THE EFFECT OF CEMENT PASTE AND FIBER CONTENT TO SLUMP AND COMPRESSIVE STRENGTH OF POLYPROPYLENE FIBER CONCRETE

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Abstract

To investigate the effects on the slump and compressive strength, this paper produced the sample groups which have the contents of cement paste (composed of cement and water) and Polypropylene fiber were fluctuated within the levels close to the value corresponding to the fundamental composition. Research results show that: The slump of the concrete mixture was directly proportional to the cement paste content but inversely directly proportional to the fiber content. When the used contents of cement paste and fiber were not too high, the compressive strength of the concrete was directly proportional to them. However, when they exceed the limit value, the compressive strength of the concrete will decrease. Synthesizing the impact on the criteria, with B15 concrete, the optimal contents of cement paste and fiber by mass were in the range of 19.1-22.4% and 1-2 kg/m^3, respectively.

Keywords: *Polypropylene fiber; fiber concrete; cement paste; slump; compressive strength.*

1. Introduction

Cement concrete (concrete) is a popular, vastly used building material with many preeminent features; however, it also has certain limitations, which must be mentioned is the weak tensile strength - poor resistance to cracking. Therefore, doing research to enhance and improve the features of concrete is very meaningful, contributing to improving the quality as well as reducing the cost of the project. The use of reinforcement fiber, which is being researched and applied by scientists in many advanced countries around the world, can innovate and improve the features of concrete effectively. There have been studies on concrete using reinforcement fibers such as: steel fiber, glass fiber, mineral fiber, organic fiber, synthetic fiber, etc. These researches focus deeply into the effects of fibers in concrete composition; degree of influence on the features of concrete and concrete mixes; choosing of the right yarn to use; determining on the optimal fiber content, etc.

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From the previous research results, it showed [1-7]: The conclusions were derived from scientific experiments and analysis, however, there have been limitations on quantity and systematic comprehensiveness; on the same research matter, with the same influencing factor but the research results were also conflicting; research on concrete using polypropylene fibers was still limited; in particular, there have been no published studies on the simultaneous effects of cement paste content and fiber content on slump and compressive strength of polypropylene fiber concrete (fiber concrete).

2. Materials and methods

2.1. Materials

The adhesive used is cement PCB-40 of Nam Son Cement Joint Stock Company. The fundamental specifications of this cement meet the provisions of Standard [8], shown in Table 1.

Table 1. The technical properties of the Portland cement PCB-40

Nº	**Typical properties**	**Request**
1	Compressive strength: - 3 days (± 45 minutes) - 28 days (± 8 hours)	 $\geq$ 21 N/mm^2 $\geq$ 40 N/mm^2
2	Setting time - Initial - Final	 $\geq$ 45 mins $\leq$ 375 mins
3	Fineness: - The amount of 0.09 mm sieve - Blain rate	 $\leq$ 10% $\geq$ 2800 cm^2/g

Fine aggregate is yellow sand derived from Red River while coarse aggregate is crushed from Hoa Thach quarry. These aggregates are commonly used in construction within the area of Chuong My district, Hanoi. The technical parameters meet the Specification [9]; The component gradation of fine aggregate and coarse aggregate are shown in Table 2 and Table 3.

Table 2. The component gradation of fine aggregate

Accumulated on the sieve, % mass				
2.5 mm	1.25 mm	630 μm	315 μm	140 μm
8	29	56	73	95

Table 3. The component gradation of coarse aggregate

Accumulated on the sieve, % mass			
40 mm	20 mm	10 mm	5 mm
0	7	55	96

Water used for concrete mixture is clean and its quality complies with the requirements specified in the Specification [10].

The reinforcement fiber used is polypropylene; the fundamental specifications and images of the fiber used are shown in Table 4 and Figure 1.

Table 4. Properties of polypropylene fiber

Properties	**Value**
Diameter	0.03 mm
Fiber length	6-12 mm
Melting point	160-170°C
Ultimate elongation	15-20%
Tensile strength	> 500 MPa
Resistance to acid and base	Good
Density	0.91 g/cm^3

Fig. 1. Polypropylene fiber

2.2. Research plan and basic experimental method

2.2.1. Research plan

On the basis of the fundamental composition of fiber concrete indicated in previous studies [11, 12], to investigate the influence of cement paste content (XN) and fiber content (P) on the slump (S) and compressive strength (R_b) of fiber concrete, this study fabricated 16 sample groups (a group includes 5 samples) with: coarse aggregate content (D) and fine aggregate (C) were fixed according to the result of fundamental component design while content of cement paste (%) and polypropylene fiber (kg/m^3) were changed respectively in the order: 17%, 19%, 21%, & 23%; and 0 kg/m^3, 1 kg/m^3, 2 kg/m^3 & 3 kg/m^3. Details of components for the fabrication of samples for slump and compressive strength are shown in Table 5.

Table 5. The composition of materials for the experimental sample groups

Nº	**D**, kg/m^3	**C**, kg/m^3	**X**, kg/m^3	**N**, lít/m^3	**P**, kg/m^3	**XN,** %
1	1197	747	240	168	0	17
2	1197	747	270	189	0	19
3	1197	747	300	210	0	21
4	1197	747	330	231	0	23
5	1197	747	240	168	1	17
6	1197	747	270	189	1	19
7	1197	747	300	210	1	21
8	1197	747	330	231	1	23
9	1197	747	240	168	2	17
10	1197	747	270	189	2	19
11	1197	747	300	210	2	21
12	1197	747	330	231	2	23
13	1197	747	240	168	3	17
14	1197	747	270	189	3	19
15	1197	747	300	210	3	21
16	1197	747	330	231	3	23

Note: cement paste content (XN) is the mass of cement and water contained in the total mass of concrete mixture.

2.2.2. The experimental method for determining the slump and compressive strength

Determination of the slump of concrete mixtures and the compressive strength of concrete was implemented according to Vietnam Specification [13, 14].

3. Results and discussion

3.1. The results of slump and compressive strength test

The test results of slump of concrete mixtures and compressive strength of concrete are shown in Table 6.

Table 6. The results of slump and compressive strength test

Nº	**XN**, %	**P**, kg/m^3	**S**, cm	**R_b**, MPa
1	17	0	4.2	15.33
2	19	0	6.7	18.66
3	20	0	8.8	21.00
4	22	0	10.7	19.62
5	17	1	3.8	14.92
6	19	1	5.3	18.75
7	20	1	7.8	22.10
8	22	1	10.3	20.70
9	17	2	3.5	14.38
10	19	2	5.3	17.53
11	20	2	7.0	22.05
12	22	2	9.2	21.12
13	17	3	2.7	13.55
14	19	3	4.3	16.69
15	20	3	5.7	21.83
16	22	3	7.5	20.97

3.2. Analyzing the slump experimental results

From the experimental results shown in Table 6, it is possible to build the relationship between the cement paste content and fiber content with the slump of the concrete mixture shown from figure 2 to 4.

From the experimental results on the relationship between the cement paste content and the slump of the concrete mixture, it is found that the slump of the fiber concrete mixture is smaller than the control concrete mixture. The slump of the concrete mixture is proportional to the cement paste content and inversely proportional to the fiber content: the smallest slump (2.7 cm) was achieved when the cement paste content is smallest (17.3%) and the fiber content is highest (3 kg/m^3); The biggest slump was collected (10.3 cm) with the highest cement content (22.4%) and the smallest fiber content (1 kg/m^3).

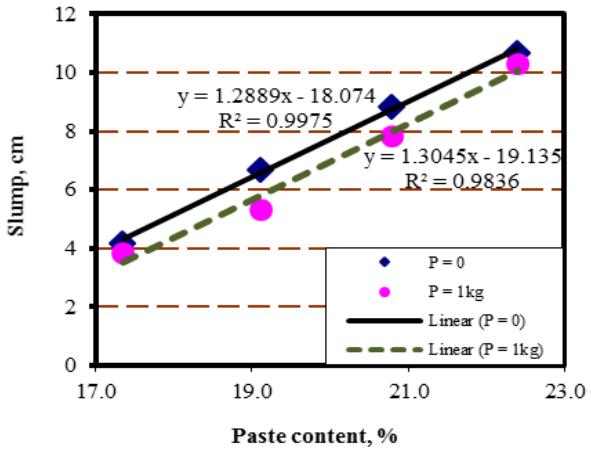

Fig. 2. The relationship between cement paste content and slump when fiber content is 1 kg/m^3

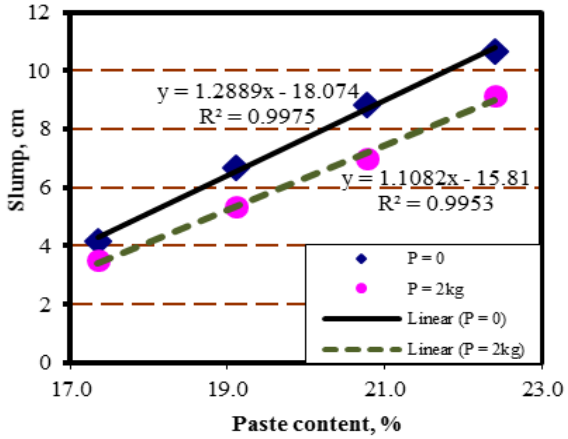

Fig. 3. The relationship between cement paste content and slump when fiber content is 2 kg/m^3

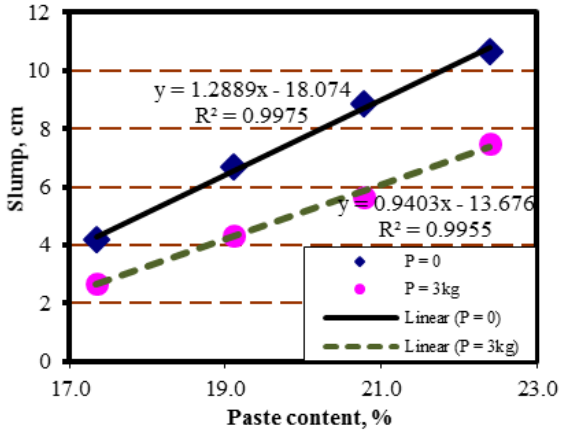

Fig. 4. The relationship between cement paste content and slump when fiber content is 3 kg/m^3

Within the scope of the study, the relationship between the cement paste content and the slump of the concrete mixture corresponding to control concrete and fiber concrete of which the fiber content of 1 kg/m^3, 2 kg/m^3 and 3 kg/m^3 were represented by equations (1) to (4), respectively.

$$S = 1.2889\ XN - 18.074 \quad (1)$$

$$S = 1.3045\ XN - 19.135 \quad (2)$$

$$S = 1.1082\ XN - 15.81 \quad (3)$$

$$S = 0.9403\ XN - 13.676 \quad (4)$$

3.3. Analyzing the compressive strength experiment results

From the test results of compressive strength in Table 6, it is possible to build a relationship between the content of cement paste and fiber with the compressive strength of the concrete, it is shown from figures 5 to 7.

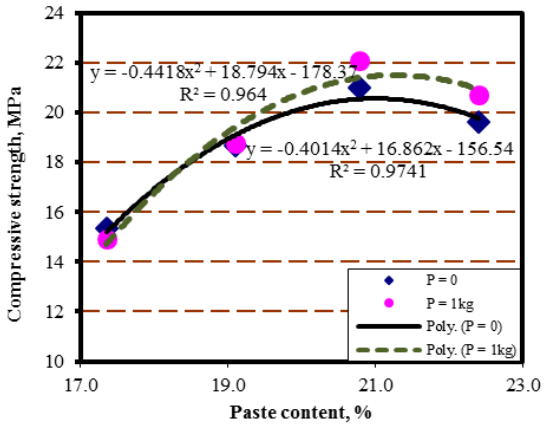

Fig. 5. The relationship between cement paste content and compressive strength when fiber content is 1 kg/m^3

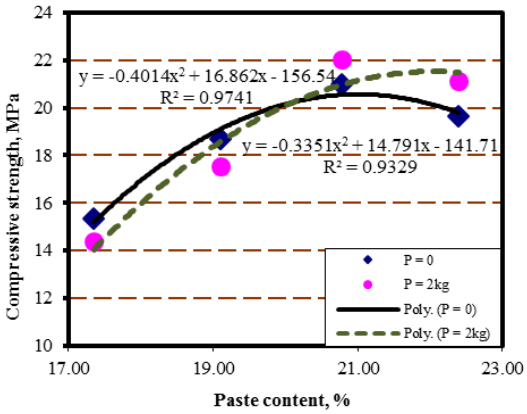

Fig. 6. The relationship between cement paste content and compressive strength when fiber content is 2 kg/m^3

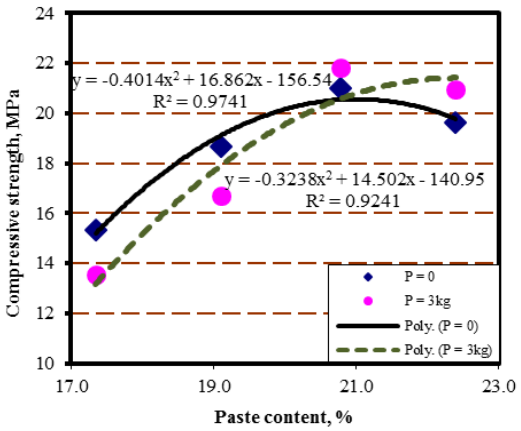

Fig. 7. The relationship between cement paste content and compressive strength when fiber content is 3 kg/m^3

From the experimental results of the relationship between the cement paste content and the compressive strength, it was found that: The maximum value of the compressive strength of the fiber concrete was higher than that of the control concrete, but the difference was not noticeable (22.1 MPa and 21 MPa). When the cement paste content and the fiber content did not exceed 21% and 2 kg/m^3, the compressive strength of the concrete was increased with the increasing of cement paste content and fiber content; when this limitation exceeded, the compressive strength of concrete tended to decrease. With the scope of the research, the compressive strength of concrete had the smallest value (13.55 MPa) when the cement paste content was the smallest (17%) and the fiber content was the highest (3 kg/m^3); compressive strength reached the maximum value (> 22 MPa) when the cement paste content was in the range of 19-22% and the fiber content was about 1-2 kg/m^3. The compressive strength of control concrete was only qualified (B15) when the cement paste content was 20%; however, when the cement paste content exceeded 20%, the compressive strength of fiber concrete still met the requirements, but tended to decrease gradually.

Within the scope of the study, the relationship between the cement paste content and the concrete strength is corresponding to control concrete and fiber concrete of which fiber content of 1 kg/m^3, 2 kg/m^3 and 3 kg/m^3 is represented by equations from (5) to (8), respectively:

$$R_b = -0.4014\ XN^2 + 16.862\ XN - 156.54 \quad (5)$$

$$R_b = -0.4418\ XN^2 + 18.794\ XN - 178.37 \quad (6)$$

$$R_b = -0.3351\,XN^2 + 14.791\,XN - 141.71 \quad (7)$$

$$R_b = -0.3238\,XN^2 + 14.502\,XN - 140.95 \quad (8)$$

4. Conclusions

The slump of the concrete mixture is proportional to the cement paste content and inversely proportional to the fiber content; however, the influence of cement paste content is much clearer while the influence of fiber content is negligible.

When the cement paste content and fiber content are not too large, the compressive strength of the concrete is proportional to the cement paste content and fiber content; when they exceed the limitation, the compressive strength of the concrete will decrease.

The compressive strength of concrete has the smallest value when the cement paste content is the smallest and the fiber content is the highest; and reaches the maximum value when the cement paste content by mass is between 19 and 22% and the fiber content is about 1-2 kg/m^3.

In the research limitation, the effect of the cement paste content and fiber content on the slump of the concrete mixture and the compressive strength of concrete is indicated by equations (1) to (8).

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ẢNH HƯỞNG CỦA HÀM LƯỢNG HỒ XI MĂNG VÀ SỢI ĐẾN ĐỘ SỤT VÀ CƯỜNG ĐỘ CHỊU NÉN CỦA BÊ TÔNG SỢI POLYPROPYLEN

Tóm tắt: *Để khảo sát sự ảnh hưởng đến độ sụt và cường độ chịu nén, chế tạo các nhóm mẫu có hàm lượng hồ xi măng (xi măng và nước) và hàm lượng sợi Polypropylen thay đổi biến động ở các mức lân cận với trị số tương ứng với thành phần cơ bản. Kết quả nghiên cứu chỉ ra rằng: Độ sụt của hỗn hợp bê tông tỉ lệ thuận với hàm lượng hồ xi măng và tỉ lệ nghịch với hàm lượng sợi sử dụng; tuy nhiên sự ảnh hưởng của hàm lượng hồ xi măng là rất rõ rệt, còn sự ảnh hưởng của hàm lượng sợi là không lớn. Khi hàm lượng hồ xi măng và hàm lượng sợi sử dụng chưa quá lớn, cường độ chịu nén của bê tông tỉ lệ thuận với hàm lượng hồ xi măng và hàm lượng sợi; còn khi vượt quá trị số giới hạn, cường độ chịu nén của bê tông sẽ giảm. Tổng hợp xét ảnh hưởng tới các chỉ tiêu, với bê tông B15 hàm lượng hồ xi măng và hàm lượng sợi tối ưu lần lượt nằm trong các khoảng 19,1-22,4% và 1-2 kg/m^3.*

Từ khóa: Sợi polypropylen; bê tông sợi; hồ xi măng; độ sụt; cường độ chịu nén.

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