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Research Paper

Experimental Research on Properties of Polymer Concrete Used for Repairing Portland Cement Concrete Pavement of Airport

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ABSTRACT

Polymer concrete (PC) is a popular construction material used for repair, thin overlays for floors and bridge decks, and other specialized fields such as precast components, machine construction. The material has many desirable properties such as fast curing, high compressive and flexural strength, high bonding to substrate, resistance to chemical agents. This study focuses on finding the suitable PC content oriented for repairing works of airfield Portland cement concrete (PCC) pavement. An experimental program was designed to investigate the mechanical properties of PC mixtures with polymer resin and filler contents varied in the ranges of 12-22 *wt*. % and 0-20 *wt*. %, respectively. The tests were conducted in accordance with the Vietnam standards system, for all samples at 2-hour-age and room condition. The test results showed that the highest values of compressive and flexural strengths and elastic modulus were 95.9 *MPa*, 18.7 *MPa*, and 37.8 *GPa*, respectively, at the same mixture of 22 *wt*. % polymer binder and 20 *wt.* % filler content. For samples of more than 18 *wt*. % of polymer binder, the direct pull-off tests demonstrated that the PC perfectly bonded to the existing PCC, with all failure locations occurred in PCC substrate. The abrasion test showed that all PC mixtures has lost only less than 0.09 g/cm^2, about one-third of regulated value for airfield pavement.

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1 Introduction

Since introduced in 1950s, PC has been increasingly used in construction industry, varying from new constructions (thin overlays for floor, bridge desk and floor) to precast components (railway sleepers, precision tool machine base) and maintenance (structure and pavement repair). PC have many prominent properties such as fast curing, high compressive and flexural strength, perfect bonding to substrate surface, or resistance to chemical agents, then it is highly appropriate for structural repair [1-8].

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In Vietnam, because of the availability constituent material in production, high bearing strength and durability in performance, PCC pavement has been widely applied in the construction of airfield components such as apron, taxiway or runway. For this type of pavement, after a certain exploitation time period, under loading and impact of environmental factors, the typical surface distresses, such as map cracking, scaling, pop-out, joint crack or spalling, corner crack etc., have been appeared on the PCC slab at different level of scale and severity. Consequently, the maintenance work has increasingly carried out corresponding to the age and pavement condition of each airport for keeping quality at a certain acceptable conditions. In general, the repair procedure applied for airport PCC pavement is similar of the highway. However, due to the restrict regulations in applying for foreign object debris (FOD) management and limit time slot arranged for maintenance activities on airfield areas in practice, there are specific requirements for the repair material and its related repair procedure. The ultimate objective is to ensure the compatible performance of the repair material and existing PCC substrate, the quality and durability of the repaired pavement areas in operation, and also the feasibility and effectiveness of repair work [9-12].

It could be found that many PC component mixtures were designed for each utilization purposes and obtained the high potential for applications in PCC airfield pavement repair. However, the high cost of the polymer binder, and the different properties between PC and PCC substrate inducing the incompatibility of the two materials in performing conditions may be the main barriers for practical application [1, 2, 11].

This paper was to find out the relevant content of PC mixtures that satisfy the practical requirements for repairing PCC airfield pavement in Vietnam conditions. An experimental program was launched to investigate the variation of main physical and mechanical properties of PC follow to the polymer binder and filler components, and define the optimized rates of the constituent.

2 Material

2.1 Binder

A two-part modified polymer matrix (denoted as Part A and Part B) was selected as the binder part of the PC mixture in this study. Table 1 shows the detailed properties of the modified polymer and its hardener.

Table 1 – Physical properties of polymer binder

Physical Indicators	Modified Polymer (Part A)	Hardener (Part B)
Mixing proportion (*wt.*)	3	1
Density (*g/l*)	3	4
Color	5	6
Physical form	Clear liquid	
Viscosity (*mPa·s*)	500 ± 50	
Hardening time (*h*)	24–36 at 25^0C	

2.2 Aggregate

The coarse aggregates are crushed stone with the diameter of 5/10 *mm*. The fine aggregates are sands with the diameter of 0/5 *mm*. The physical characteristics of aggregates are presented in Table 2.

Table 2 – Physical properties of aggregate (CS)

Index	Crushed stone (C)	Sand (S)
Petrography nature	Calcareous	Siliceous
Particles size (mm)	5-10	0-5
Shape	Round	Round
Specific gravity (kg/m^3)	2700	2700

2.3 Filler

The filler used for making PC mixture is Portland cement PC40Nghi Son. The physical properties of cement presented in Table 3.

Table 3 – Physical properties of filler (*F*)

Passing 45 *μm* (% *wt.*)	Passing 5 *μm* (% *wt.*)	Specific gravity (g/cm^3)	Blaine fineness (cm^2/g)
94.82	22.66	3.12	4,100

3 Experimental program

3.1 PC mixtures for test

The PC mixtures were prepared for experiment test by changing the proportion of its material contents. The ratios by weight of three contents are presented in Table 4.

Table 4 – PC mixtures (*wt.* %)

Sample Denote	Binder (B)	Agg. (CS)	Filler (F)
B12-F0	12	88	0
B12-F10	12	78	10
B12-F20	12	68	20
B15-F0	15	85	0
B15-F10	15	75	10
B15-F20	15	65	20
B18-F0	18	82	0
B18-F10	18	72	10
B18-F20	18	62	20
B20-F0	20	80	0
B20-F10	20	70	10
B20-F20	20	60	20
B22-F0	22	78	0
B22-F10	22	68	10
B22-F20	22	58	20

3.2 Test method

The materials for making samples were prepared with the mix proportions presented in Table 4. The samples' dimensions and testing procedure standards were showed in Table 5.

Table 5 – Physical properties of aggregate (*CS*)

Testing indicators	Sample dimension (*mm*)	Test standard
Compressive strength	100 × 100 × 100	TCVN 3118 : 1993
Flexural strength	100 × 100 × 600	TCVN 3118 : 1993
Elastic modulus	D150, H300	TCVN 5276 : 1993
Bond strength	D50	TCVN 9491 : 2012
Surface abrasion	70 × 70 × 150	TCVN 3114 : 1993

4 Result and Discussion

4.1 Compressive strength

The tests for measuring compressive strength of PC were conducted according to TCVN 3118: 1993 [13]. The testing results showed in Fig. 1 indicate that the compressive strength of 12 *wt*. % polymer binder group increased with 10 *wt*. % filler added, but with 20 *wt*. % filler, the one slightly decreased comparing to that of 10 *wt*. % filler group. For the 15, 18, 20, 22 *wt*. % polymer binder groups, the compressive strength increased up to 20 *wt*. % of filler content, but the increasing rate between 10 and 20 *wt*. % filler groups is lower than that of between 0 and 10 *wt*. % groups. The results also show that the compressive strength of with-filler group averagely increase of 32.5, 53.4, 45.9, 16.8, 14.4 %, corresponding to 12, 15, 18, 20, 22 *wt*. % of polymer binder, comparing to without-filler group.

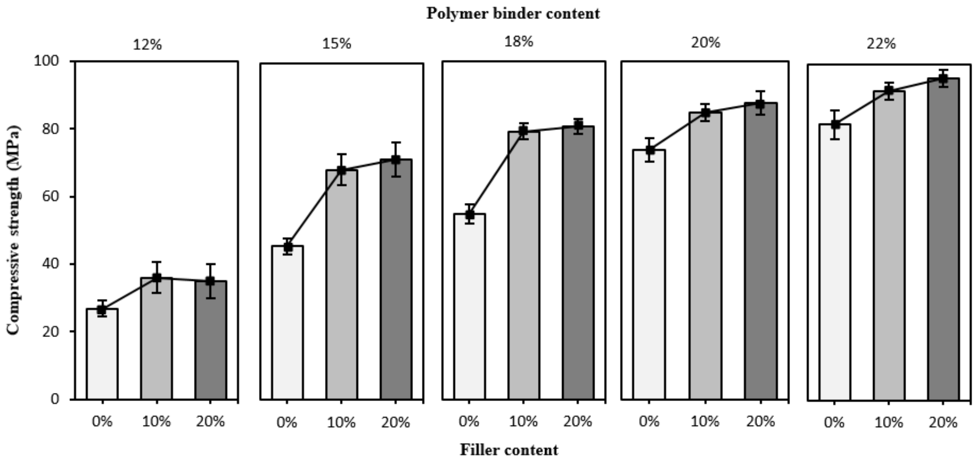

Fig. 1 – Compressive strength of PC vs. polymer binder and filler contents

For without-filler group, compressive strength increased proportionally with polymer binder content, however the increase rate diminished at high ratios of 20, 22 *wt.* %. It also should be noticed that except without-filler samples, the compressive strength of samples having more than 18% of polymer binder content have no significant increment.

4.2 Flexural strength

The tests for measuring flexural strength of PC were conducted according to TCVN 3119: 1993 [14]. The testing results showed in Fig. 2 reveal that the flexural strengths of PC mixtures having filler groups averagely increase of 51.8%, 38.6%, 15.0%, 7.8%, 7.0% comparing to PC mixtures without filler content, corresponding to 12, 15, 18, 20 and 22 *wt*. % of polymer binder contents.

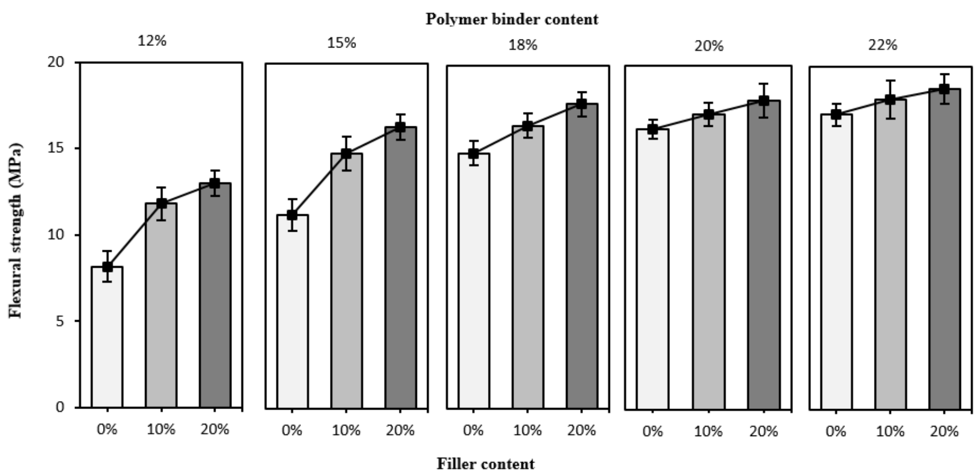

Fig. 2 – Flexural strength of PC vs. polymer binder and filler contents

From the graphs, there are two broken points describing the big changes of flexural strength of PC from without to with 10 and 20 *wt*. % of filler in the mixture. From the graphs of 18, 20 and 22 *wt*. % of polymer binder, it is easy to recognize the correlation between flexural strength and added filler ratio is very close linear, with high R2 values of 0.995, 0.999 and 0.986, respectively. However, the slopes are gradually flatter from 18 to 22 *wt*. %, revealing the diminished effect of filler content in PC mixtures with high proportion of polymer binder content.

4.3 Elastic Modulus

The elastic modulus (EM) of PC was determined by method of static compressing cylindrical samples according to TCVN 5276 : 1993 [15]. The testing results presented in Fig. 3 expressed a close linear relationship between EM and filler content proved by high squared correlation R2 coefficients of 0.998, 0.997, 0.991, 0.999, 0.995, corresponding to the proportions of 12, 15, 18, 20 and 22 *wt*. % of polymer contents in the mixtures.

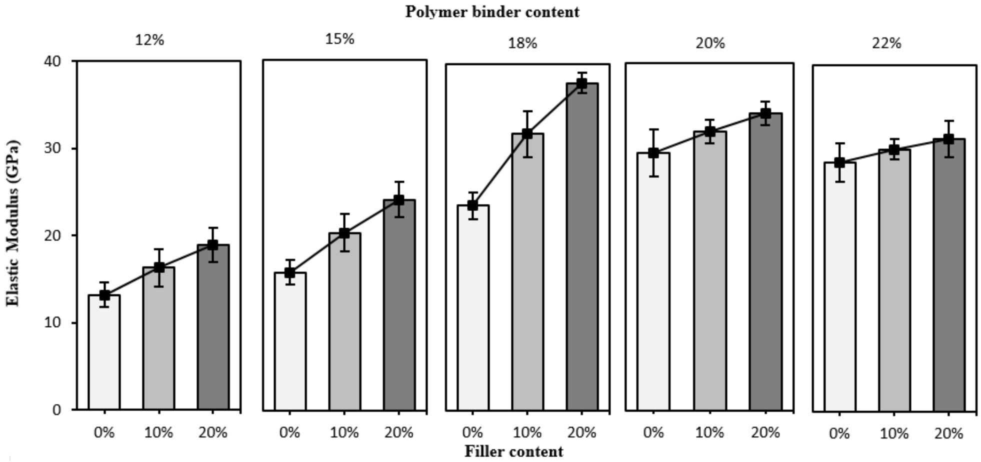

Fig. 3 – Effect of polymer binder and filler contents on elastic modulus of PC

The additional filler content in the PC mixtures resulted in the average increase of EM of PC of 33.7%, 40.8%, 47.4%, 11.8%, 7.4% comparing to the groups of samples without filler, corresponding to 12, 15, 18, 20, 22 *wt*. % of polymer binder contents. The EM values increase in all groups, the rates steadily rise up from group 12 *wt*. % to 15 *wt*. % groups, attain highest at 18 *wt*. % group, and then descend in groups of 20, 22 *wt*. % groups. Fig. 4 represented the EM and corresponding density of PC samples at different ratios of polymer binder and filler contents. The results showed that the EM and density had the same trend, with high correlation of 0.949 between sets of the two variables.

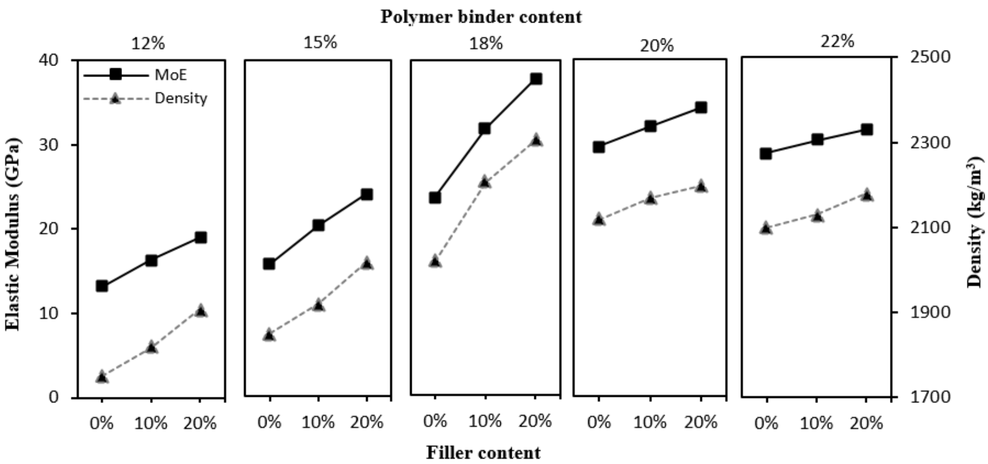

Fig. 4 – Correlation between elastic modulus and density of PC

4.4 Bonding strength

The bond strength of PC to PCC substrate was determined by pull-off test according to TCVN 9491:2012 [16]. A set of cubic PCC samples with dimensions of 300 × 300 × 300 *mm*, having 28-days compressive strength of 40 *MPa* were prepared as substrates for pull-off tests. The bond strength measured from tests are demonstrated in Fig. 5.

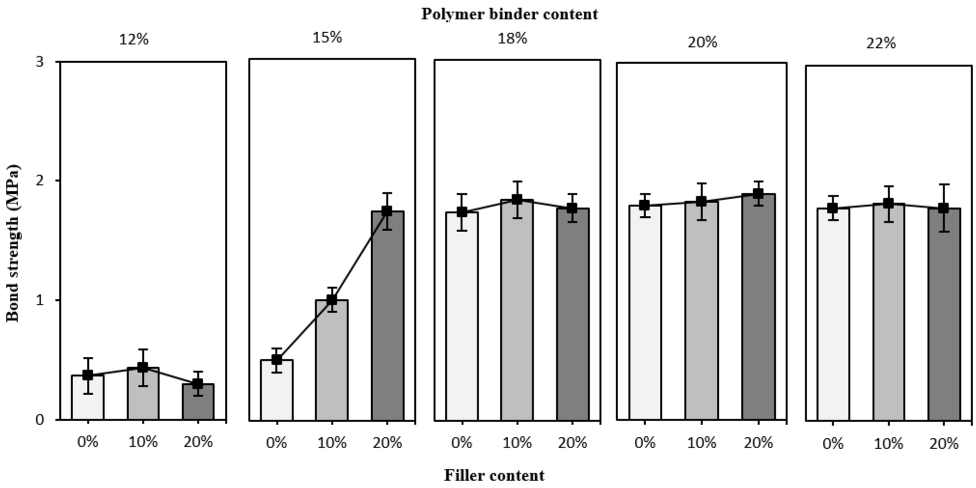

Fig. 5 – Correlation between elastic modulus and density of PC

The testing results indicated that the PC of 12 *wt*. % of polymer binder weakly bonded to the substrate. The failures of samples occurred at the interface between PC and PCC substrate. The bond strength recorded from the test was slightly increase for the PC samples with 10 *wt*. % of filler content, but decrease for the ones with 20 *wt*. % of filler content. For PC with 15 *wt*. % of polymer binder, there were two types of failures: all the PC samples without and with 10 *wt*. % of filler de-bonded at PC/PCC substrate interface; the PC samples with 20 *wt.* % of filler showed the failure in PCC substrate. The bond strength of PC at 15 *wt*. % of polymer binder content significantly increased for samples with 10, 20 *wt*. % of filler content comparing to samples without filler. For the PC samples prepared at 18, 20 and 22 *wt*. % of polymer binder content, the all tests showed that the failure locations were in PCC substrate. Therefore, the effect of filler content in PC mixtures on bond strength is ambiguous.

4.5 Surface Abrasion

The all combinations of polymer binder and filler contents showed in Table 4 were prepared for determining the surface abrasion according to the standard of TCVN 3114: 1993 [17]. The test results showed that the surface abrasion values varied in a narrow range from 0.07 to 0.09 g/cm^2. It also did not clearly reflect the relationship between polymer binder and filler contents in the PC mixtures.

5 Conclusions and remarks

In this study, the effect of polymer binder and filler contents on the physical and mechanical properties of PC, orienting for application in PCC airfield pavement repair, were examined. The study results showed that:

(1) The PC samples quickly cure at room conditions. The all mechanical properties of PC mixtures were tested in the at 2-hour age;

(2) The addition filler in a range of 10-20 *wt.* % improved the compressive, flexural and elastic modulus of PC by an average of 14.4-32.5%, 7.0-51.8%, and 7.4-47.4%, respectively at polymer binder content varying from 12 to 22 *wt*. % comparing to the PC samples without filler added;

(3) The PC having polymer binder content in a range of 18-22 *wt.* % performed a complete adhesion to PCC substrate representing by pull-off failure occurred in PCC substrate. The effect of added filler on bond strength is not clear;

(4) The surface abrasion of studied PC sample is in a narrow range of 0.07-0.09 g/cm^2, about 3 times lower than allowable value of 0.3 g/cm^2 regulated for airport pavement;

(5) The studied PC contents with 18-22 *wt*. % of polymer binder and 10-20 *wt*. % filler content can meet the primary requirements of a material using for surface PCC airport pavement repair [18, 19].

The research results of experimental program presented that the mechanical properties of PC material extremely higher than that of PCC, and meet very well the requirements from practice, especially for the curing time, the compatible performance with common PCC airfield pavement and its related application technology. It proved to be a high potential solution for surface distresses treatment of airfield PCC pavement in Vietnam.

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