Mechanical and Physical Properties of Concrete Modified with Natural Rubber Latex

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Abstract. To improve the performance of concrete, natural rubber latex (NRL) is mixed with concrete. It has been observed that rubber latex-modified concrete is more durable than conventional concrete due to superior strength. This study analyzed the physical and mechanical properties of concrete mixed with natural rubber latex. In this research, impacts of natural rubber latex on workability, bleeding of concrete, compressive strength, tensile strength, flexural strength, bond stress and water absorption using concrete with a nominal concrete mix proportion of 1:2:4 (cement : sand : gravel) by volume. Rubber latex-modified concrete compositions containing 0%, 1%, 3%, 5%, 10%, and 15% by weight of cement were prepared or polymer concrete ratio (P/C), and the strength of the structure was tested after 28 days. The results indicated that the polymer cement ratio (P/C) of 1% gives the best performance with 245 ksc compressive strength, 35 ksc tensile strength, 46 ksc flexural strength, 34 ksc bond stress and average water absorption was 0.95%. Based on the results of this study, polymer cement ratio (P/C) of 1% by weight is most recommended to be used with various types of concrete structures.

Key words: natural rubber latex, concrete, mechanical, polymer cement ratio

1. Introduction

Concrete made with Portland cement has been a popular construction material in the world for the past 200 years or more. Concrete is the most preferred construction materials on earth, but it has some limitations which inevitably affects its quality and general performance. These limitations include; delayed hardening, inherent brittleness, weak tensile capacity, low flexural strength, small failure strain, large drying shrinkage, susceptibility to frost damage, high moisture absorption and most critically low resistance to chemicals. To improve on these deficiencies, elastomers are added as modifiers [1, 2, 3, 4]. In addition, concrete have some disadvantages such as delayed hardening, low tensile strength, large drying shrinkage, and low chemical resistance. To reduce these disadvantages, many attempts to use polymers or natural rubber latex have been made. Latex modified concrete have good binding properties and good adhesion with aggregates. Natural rubber latex has long chain structure which helps in developing long range network structure of bonding. In contrast, cement materials provide short range structure of bonding [5]. As a result natural rubber latex materials usually provide superior compressive, tensile and flexural strength to the concrete compared to concrete without latex [6].

Since rubber was first introduced to Thailand in the early 1900s, the country has grown to become the world's number one producer and exporter of natural rubber due to its tropical climate as well as effective and advanced cultivation methods. Beginning with an initial planting in Trang Province in the southern part of Thailand, the cultivation area has since grown to surpass 3.5 million hectares throughout the country. The transition to becoming the number one producer is a testament to the industry's focus and drive. Thailand stepped into the first rank in producing and exporting the natural rubbers by producing and exporting at 34% and 47% of overall capacities in the world. Nowadays, several researches in Thailand study the applications of latex for utilizing in construction materials. For example, (i) the development of irrigation canal mix with rubber latex for farm irrigation system [7], (ii) application of rubber latex and soil cement develop drought relieving water pond [8], and (iii) the development of coating material mixed with rubber latex for irrigation canal maintenance [9]. This research analyzed the physical and mechanical properties of concrete mixed with rubber latex (pre-vulcanized latex)for the development of irrigation canals. The experiment was performed in a laboratory to test the properties of the mixture in terms of workability, bleeding of concrete, compressive strength, tensile strength, flexural strength, bond stress and water absorption ratio.

2. Materials and method

2.1 Cement

Ordinary Portland cement of 53 grades conforming to ISI standards has been procured and the properties of the cement are investigated in the laboratory (Fig. 1)

2.2 Fine aggregate

The locally available river sand conforming to grading zone-II of IS 383-1970 has been used as Fine Aggregate. The Specific Gravity of fine aggregates is 2.69 with a fineness modulus of 2.77

2.3 Coarse aggregate

Natural granite aggregate having fineness modulus of 7.1 was used.

2.4 Water

Water which is free from all organic impurities is used to develop this concrete mix in the study.

2.5 Rubber latex

Natural rubber latex was used for this research.

Figure 1. concrete material : Coarse aggregate, Fine aggregate, cement and rubber latex

2.6 Mix design of concrete

The Dry Loose Bulk Densities (DLBD) method is an accurate method to calculate cement, sand and aggregate for a given nominal mix concrete. This gives accurate results as it takes into account the Dry Loose Bulk Densities of materials like Sand and Aggregate which varies based on the local source of the material. For calculation, we consider a nominal concrete mix proportion of 1:2:4 (Grade of concrete M20-1:2:4) and water cement ratio 0.55. So, the following are the materials required to produce 1 cum of concrete of a given nominal mix proportion will require cement 316 kg, sand 704 kg, aggregate 1450 kg and water 174 kg.

2.7 Latex Modified Concrete (LMC)

In this research, latex modified concrete compositions containing 0%, 1%, 3%, 5%, 10%, and 15% natural rubber latex (Table 1) by weight of cement were prepared or polymer concrete ratio (P/C). Therefore, one bag of cement (50 Kgs) has to be mixed with 115 kgs of Sand, 209 Kgs of aggregate and 27.5 kgs of water to produce M20 grade (Table 2) concrete for polymer cement ratio 0%. Table 1 shows amount of Polymer and cement (P/C) were mixed in different proportions of 0%, 1%, 3%, 5%, 10% and 15% by weight to prepare the solution and was further added to one bag of cement (50 Kgs).

Table 1. Polymer cement ratio (P/C) 0%, 1%, 3%, 5%, 10% and 15% (by weight) and amount of water and latex for cement 50 kg

P/C	Solid)kgs)	Latex)kgs)	Water)kgs)
0%	0	0	27.50
1%	0.5	0.83	27.17
3%	1.5	2.50	26.50
5%	2.5	4.16	25.84
10%	5	8.33	24.17
15%	7.5	12.5	22.50

Table 2. The mix ratios of the cement type for 50 kg in the research

Materials	Weight (kg)					
	P/C =0%	P/C =1%	P/C =3%	P/C =5%	P/C =10%	P/C =15%
Cement	50	50	50	50	50	50
Fine aggregate	115	115	115	115	115	115
Coarse aggregate	209	209	209	209	209	209
Water	27.5	27.17	26.5	25.84	24.17	22.5
Latex	0	0.83	2.5	4.16	8.33	12.5
Total	401.5	402	403	404	406.5	409

2.8 Curing

The moulds were removed after 24 hours and the specimens were covered by plastic (Fig. 2). After curing the specimens for a period of 28 days the specimens were removed out and allowed to dry under shade

Figure 2. Curing of specimen

3. Experimental work and discussion

3.1 Workability

The result for the workability of concrete mixed with natural rubber latex is shown in Fig. 3. The graph shows data between slump test and the percentage of polymer cement ratio (P/C) mixed with concrete. It is clear that rubber latex has effect on slump of concrete that this revealed a decrease in the workability with an increase in polymer cement ratio. The use of rubber latex to partially replace cement (P/C = 1%, P/C =3% and P/C =5%) slightly reduced the slump approximately 1 cm to 2 cm when it compare with normal concrete (P/C = 1%). However, there was a significant decrease in slump of concrete mixed with polymer cement ratio (P/C) of 10% and 15% around 4.5 cm to 7.5 cm (Fig. 4). The reduction in workability with increase polymer cement ratio is due to the nature of polymer particles which repels water.

Figure 3. Slump test of concrete

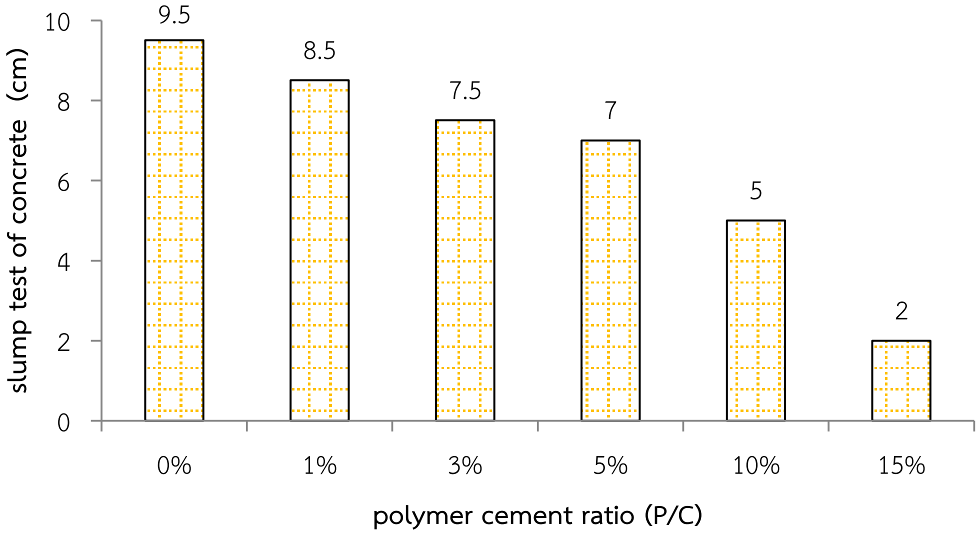

Figure 4. Workability of fresh concrete mixed with natural rubber latex

3.2 Compressive strength of concrete

Compressive strength tests were conducted on cured cube specimen at 28 days age using a compression testing machine of 200 tons capacity. The cubes were fitted at centre in compression testing machine and a very small load was applied to keep the cube in position. The load was then slowly applied to the tested cube until failure as Figure 5. For the concrete the compression strength is the main criteria to know the mechanical properties of the concrete, here the compressive strength of concrete is conducted for the various percentages of the pre-vulcanized rubber latex added concrete, compression strength of the pre-vulcanized rubber latex added concrete was increased for the lower percentage of the pre-vulcanized rubber latex, at the 5% of the polymer cement ratio (P/C) compression strength is increased there after compression strength of the pre-vulcanized rubber latex added high strength concrete is decreases therefore the optimum percentage of the natural rubber latex for the compression is 5%. Figure 6 shows the comparison of compressive strength concrete between normal concrete and rubber latex modified concrete with addition of 5, 10 and 15% of pre-vulcanized rubber latex. Focusing on the outcome of the result it can be seen that normal concrete (P/C=0%) gives higher compressive strength when compared with other rubber latex modified concrete. The impact of the latex inclusion is clearly seen as the modified concrete entertained little reduction in compressive strength when compared with the normal concrete. This is because the curve for the normal concrete is going down more than the curves for the modified concrete.

Figure 5. Cube specimen compressive strength test

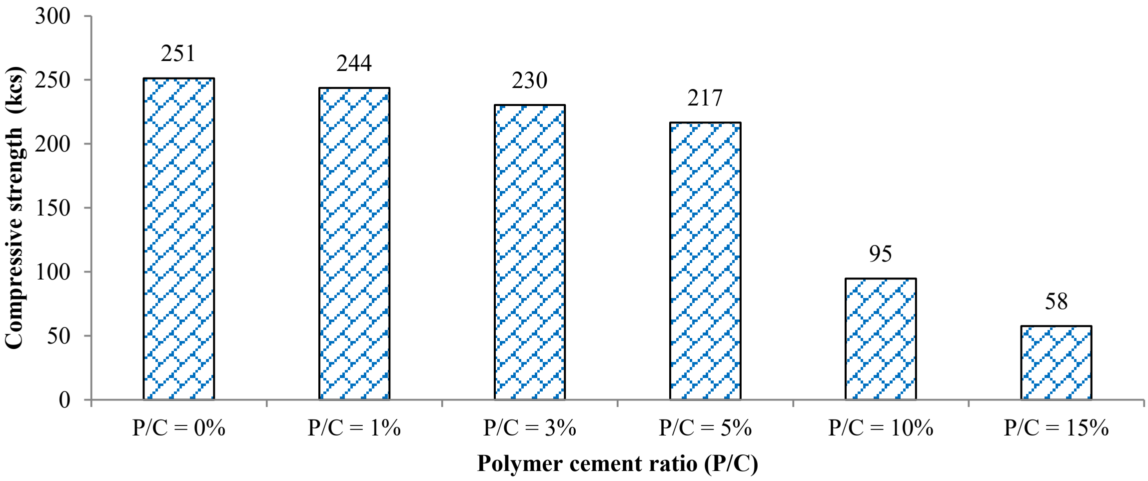

Figure 6. Effect of natural rubber latex on compressive strength of concrete

3.3 Flexural strength of concrete

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam to resist failure in bending (Fig. 7). The flexural strength is also one of the main criteria for finding the mechanical properties of the concrete. Here the flexural strength of the concrete was observed that due to the effect of rubber latex flexural strength of the natural rubber latex added high strength Concrete (42 ksc to 46 ksc) is increased as polymer cement ratio between 1% to 5%. Fig. 11 shows the flexural strength results of concrete mixed with natural rubber latex. Therefore optimum polymer cement ratio is 1% for the flexural strength (46 ksc) of natural rubber latex added concrete.

Figure 7. Beam specimen loading arrangement (flexural strength test)

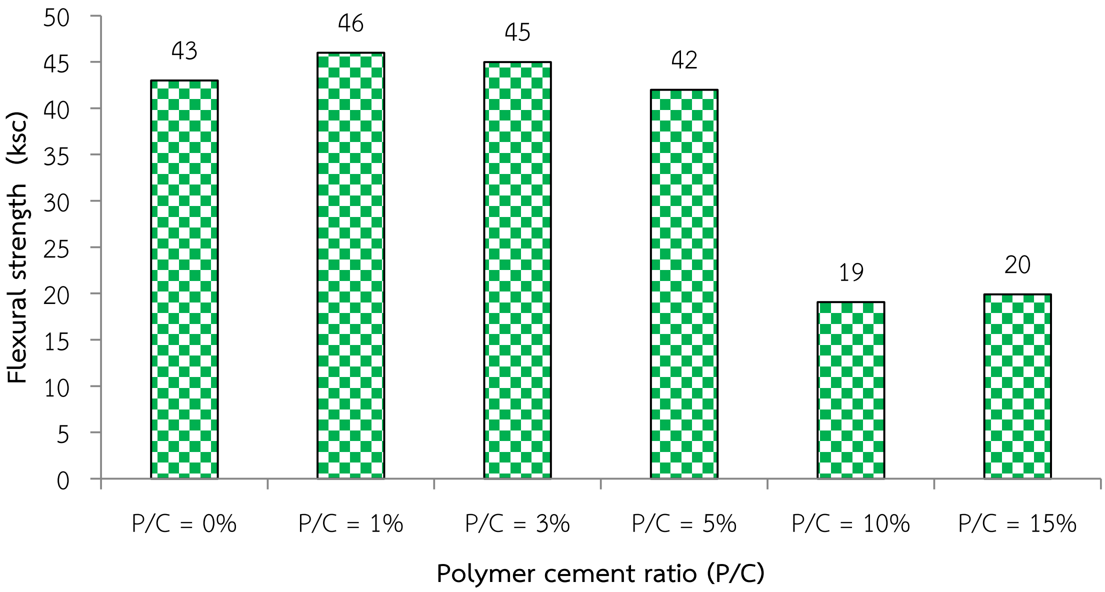

Figure 8. Effect of pre-vulcanized rubber latex on flexural strength of concrete

3.4 Water absorption of concrete

Fig. 9 shows the water absorption result conducted on rubber latex modified concrete. It can be seen from the figure that 1% of polymer concrete ratio provide the most effective dosage among other quantities used as it allows for minimum water absorption (0.95%) in the concrete. Normally, latex-modified concrete [5] have a structure in which larger pores can be filled with polymers therefore reducing water absorption, water permeability and water vapor transmission. However, specimens with higher than 5% of polymer cement ratio give poor water exclusion properties toward concrete [6]. This is probably due to excess latex pushing aggregates further away thus creating a room for higher absorption. In addition, physical observations during the experiment have clearly indicated a technical lapse in the suitability of this method in assessing the water absorption of latex modified concrete.

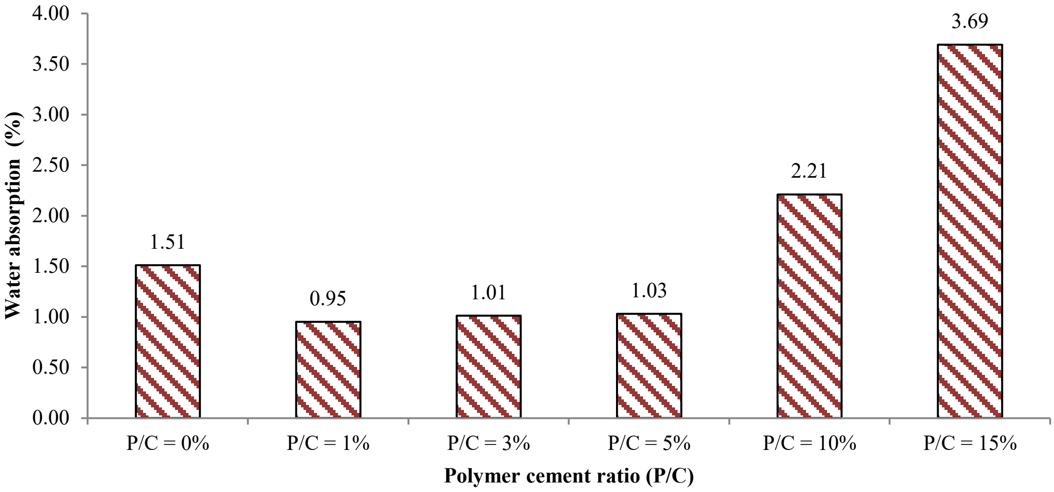

Figure 9. Effect of natural rubber latex on water absorption of concrete

4. Conclusions

This study analyzed the physical and mechanical properties of concrete mixed with natural rubber latex. The polymer cement ratios (P/C) for this testing are 0%, 1%, 3%, 5%, 10%, and 15% by weight of cement were prepared concrete with a nominal concrete mix proportion of 1:2:4 (cement : sand : gravel) by volume. The results indicated that the polymer cement ratio (P/C) of 1% gives the best performance with 245 ksc compressive strength, 35 ksc tensile strength, 46 ksc flexural strength, 34 ksc bond stress and average water absorption was 0.95%. Based on the results of this study, polymer cement ratio (P/C) of 1% by weight is most recommended to be used with various types of concrete structures such as concrete canal lining and concrete pond lining. In addition, Based on the results and observations made in this experimental research study, the following conclusion are drawn:

1. By the addition of natural rubber latex, there is an decrease in the workability of concrete as the polymer content increased.
2. The presence of natural rubber latex is proved to be effective to reduce the ingress of water in concrete. However, for the mixes rich in cement, the dosage of natural rubber latex should be so adjusted that the workability of concrete should remain in controlled limits to avoid the highly flowable concrete due to plasticizing effect of natural rubber latex.
3. There is an improvement in the strength of concrete as the polymer content increased in the mix of various percentage of natural rubber latex of concretes tested in this investigation.

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