Behaviors of High Strength Concrete Containing Para Rubber Latex and Rubber Sludge

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***Abstract*— The objective of this study was to investigate the behaviors of high strength concretes containing concentrated latex and rubber sludge such as workability, compressive strength and tensile strength. The designed strength was 45 MPa. The required slump was from 7.5 to 12.5 cm. The water in mixture proportions was substituted by the latex at the rates of 0.5% and 1.0% by weight while the fine aggregate was replaced at the rates of 2.0% and 4.0% by volume. The mold dimension was in cylindrical shape with 10 cm of diameter and 20 cm of height. The concrete specimens were observed at the ages of 3, 7, and 28 days of curing for the compressive strength and at the age of 28-day curing for the tensile strength test. The result showed that the workability of high strength concrete increased when it contained the para rubber latex. However, it decreased when the percentage of concentrated latex and rubber sludge increased. In addition, the compressive strength of 0.5% latex-concrete was higher than the that of control sample while the 1.0% latex-concrete provided a lower strength. Moreover, the mixtures that contained both latex and sludge gave less strengths while the amount of sludge replacement increased. At 28-day curing, most of mixtures provided better tensile strengths except the sample with 1.0% latex and 4.0% sludge. The 0.5% latex-concrete produced the highest tensile strength.**

Keywords*— *Compressive strength, workability, tensile strength, para rubber latex, and rubber sludge.

I. Introduction

One of the most important plants in Thailand is rubber plant and it also plays as a significant part to support Thai economy because it has been used with a massive amount every year, especially during 2006 to 2008, it was produced more than 3 million tons for each year [1] in order to produce products in various forms for local distribution and exporting to overseas intensely. One-third of the whole natural fresh rubber comes from the eastern region of the country. Regrettably, in the last ten years, its price has been decreasing continuously [2]. It incurs badly effect to many sections, for instance agriculture, economy, politics, environment, and so on. Moreover, the production, which reforms fresh rubber into many kinds of products, has left over a massive by-product called rubber sludge. The rubber sludge has been used as a useful raw material for fertilizer production in agricultural field. Notwithstanding, the rest amount of this sludge still becomes a big concern for Thai government due to its stinky smell. To solve these issues, there were many researches and projects involved with para rubber latex such as the study about asphalt-latex combination [3-4], concrete containing rubber latex [5], for example.

II. Experimental Program

This study would focus on the high strength concrete with the 45MPa of designed strength. It was designed by following the ACI Standards [6]. The slump interval was from 7.5 to 12.5 centimeters. The replacement rates of 0.5% and 1.0% by weight of water in the mixtures were replaced with para rubber latex simultaneously while 2.0% and 4.0% by volume of fine aggregate in each mixture were replaced with para rubber sludge. The compressive strength was tested at the ages of 3, 7, and 28 days of curing respectively, while the tensile strength was investigated only at the age of 28 days of curing. Three samples were prepared for each test curing ages of every mixture. Mold dimension was a cylindrical shape with 10 centimeters of diameter and 20 centimeters of height.

A. Material Preparation

Both coarse and fine aggregates must be washed by clean water and well- dried in the air. The coarse aggregate has to be screened to ensure its size was greater than 0.187 inch by using only the one which retained on a sieve No.4. The fine aggregate has to be screened by passing a sieve No. 4 and retained on a sieve No.100. Since the sludge was used to replace with fine aggregate, making certain that it was dry very well and then sieve it so that their overall sizes were similar. The concentrated latex came from DS. Rubber Co., Ltd Company, Rayong Province, Thailand. Chemical Admixture Type G confirming by ASTM C494/494M [7] was used for the high strength in order to maintain slump of fresh concrete.

B. Material Properties

After preparing all materials, they all were tested one by one so that we could acknowledge their properties. For coarse aggregate, its unit weight, maximum size, specific gravity, and water absorption are 1,603.4 kg/m^3, 20 mm, 2.765, and 0.37% respectively. Moreover, fine aggregate's fineness modulus is 2.65. Its specific gravity equals to 2.63 and 0.44% for water absorption. Portland cement type I with specific gravity of 3.15 confirming ASTM C150/150M [8] and tap water were selected. The latex was concentrated with 61.96% of minimum solid content, 60.92% of minimum dry rubber content and milky color. The rubber sludge with 2.491 of specific gravity was used as fine aggregate replacement. It was tested by following the same way as cement specific gravity test method.

C. Mix design

The specimen proportions for this high strength concrete were designed base on ACI 211.1-91 [9] with the required strength and slump as mentioned previously. All designed mixtures' proportions for getting 1 cubic meter of concrete are shown in TABLE 1. For the high strength concrete, the superplasticizer at the rate of 0.6% by mass of cement or 3.2 kg/m^3 for control mixture and its slump was 9 cm. Thus, the rest mixtures had to be added 3.2 kg/m^3 for following those in control mixtures as well.

TABLE I. THE MIX PROPORTIONS FOR 1 CUBIC METER OF CONCRETE CONTAINING PARA RUBBER LATEX AND SLUDGE

Mixture	**Compressive strength: 45 MPa**						
	Cement (kg/m^3)	***Coarse Agg. (kg/m^3)***	***Fine Agg. (kg/m^3)***	***Water (kg/m^3)***	***Latex (kg/m^3)***	***Sludge (kg/m^3)***	***Superplasticizer needed (kg/m^3)***
Control	526	1018	644	207	-	-	3.2
[a]HRL0.5	526	1018	644	206	1	-	3.2
HRL0.5+[b]RS2	526	1018	632	206	1	8	3.2
HRL0.5+RS4	526	1018	619	206	1	16	3.2
HRL1.0	526	1018	644	205	2	-	3.2
HRL1.0+RS2	526	1018	632	205	2	8	3.2
HRL1.0+RS4	526	1018	619	205	2	16	3.2

[a]HRL: High strength concrete with rubber latex

[b]RS: Rubber sludge

D. Concrete Mixing Procedure

A drum mixer was used for mixing concrete in this research. The required quantity of sludge must be combined well with the fine aggregate beforehand outside the mixer and in the same way, the concentrated latex had to be mixed with water as a solution before adding into the mixer. Then, the mixing proceeds based on the ASTM C192/192M [10]. For the high strength concrete mixing, the superplasticizer Type G must be added as an admixture to maintain its slump. The slump was observed by following the ASTM C143/143M [11]. It is important to know that the fresh concrete should be used within 30 minutes after taking out from the drum mixer to control its properties.

E. Concrete Molding and Curing

The cylindrical molds with 10 cm of diameter and 20 cm of height were needed in this study. Moreover, they were cast molds because they completely do not react to the concrete containing Portland cement ASTM C470/C470M [12]. The fresh concrete was filled into the molds by divided to 3 layers. Each layer was tamping for 25 times by using a round steel bar measured 16 mm of diameter and 61 cm of length. While tamping the second and third layers, the steel bar must be penetrated around 2.5 cm into the first and second layers, respectively. The proper ambient temperature was between 20 and 30°C.

F. Compressive and Tensile strengths Test Procedure and Calculation

The specimens were brought out of the water and kept them covered with wet burlap to keep them moist. After that, their dimensions and weight were recorded. A neoprene cap was applied on the ends of the specimens to level a planar surface while loading. They were placed vertically into the machine and gradually applying load until failure.

The compressive strength would therefore correspond to the point on the engineering stress-strain curve defined by

$$\sigma_C = F/A \qquad (1)$$

Where, σ_C: compressive strength of concrete

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F: vertical load applied just before the samples cracked
A: surface area of the sample

First, the concrete samples had to wiped and removed any surface moisture. The test specimen shall be placed in the centering jig with packing strip or loading pieces carefully positioning along the top and bottom of the plane of loading of the specimen. it shall be ensured that the upper platen is parallel with the lower platen. The tensile strength calculation of concrete was defined by the following formula:

$$\sigma_T = 2P/\pi dL \qquad (2)$$

Where, σ_T: splitting tensile strength of concrete
P: maximum vertical applied load indicated by the testing machine
d: diameter of the sample
L: average length of the sample

III. RESULTS AND DISCUSSION

A. *The Workability Result*

The mixtures with constant 0.5% of latex and 0%, 2.0%, and 4.0% of the sludge substitution gave the slumps of 11, 7, and 6.8 cm, respectively. Moreover, the mixtures containing 1.0% of latex with 0%, 2.0%, and 4.0% resulted 10, 7, and 6 cm of the slump respectively as shown in TABLE II. These proved that the superplasticizer was highly effect on concrete workability. In addition, the slump level decreased when the quantity of the rubber sludge increased in each mixture proportion. On the other hand, the latex seemed not effect much on the high strength concrete's slump.

TABLE II. THE SLUMP TEST RESULT

Mixture	Slump Result (cm)
Control	9.0
HRL0.5	11.0
HRL0.5+RS2	7.0
HRL0.5+RS4	6.8
HRL1.0	10.0
HRL1.0+RS2	7.0
HRL1.0+RS4	6.0

B. *The Compressive Strength Result*

The compressive strength result was indicated in TABLE II and Fig. 1. At the ages of 3, 7, and 28 days of curing, the compressive strength of HRL0.5 was higher than the control sample's while that of HRL1.0 was lower. A small amount of the latex helped reducing the concrete porosity yet it gave reverse result if there was greater and equal to 1.0% of concentrated latex. For the mixtures containing the latex 0.5 % with 0%, 2.0%, and 4.0% of sludge had dramatically decreased, respectively, even lower than the control one's. Moreover, it showed the same way and reasons for the mixtures containing constant 1.0% of latex with 0%, 2.0%, and 4.0% of sludge substitutions. It could be assumed that this happened due to the strength of fine aggregate was better than that of sludge. The latex-concrete containing 2.0% of sludge gave better strength than the one containing 4.0% of sludge. The reason was the sludge particles distracted the hydration reaction of cement molecules as shown in Fig. 2 (a) and (b). The more the sludge substitution the lower the compressive strength.

TABLE III. THE COMPRESSIVE STRENGTH RESULT

Mixture	Compressive Strength (kg/cm²)		
	3 days	*7 days*	*28 days*
Control	305.0	353.6	389.3
HRL0.5	298.9	374.6	391.9
HRL0.5+RS2	276.9	326.8	365.6
HRL0.5+RS4	264.5	282.1	339.0
HRL1.0	283.8	315.7	382.9
HRL1.0+RS2	270.5	312.0	325.9
HRL1.0+RS4	273.5	288.5	324.0

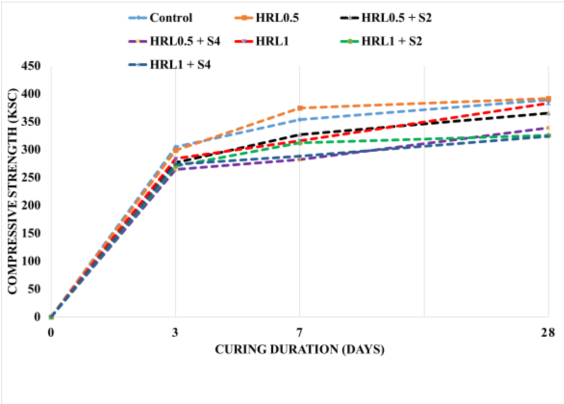
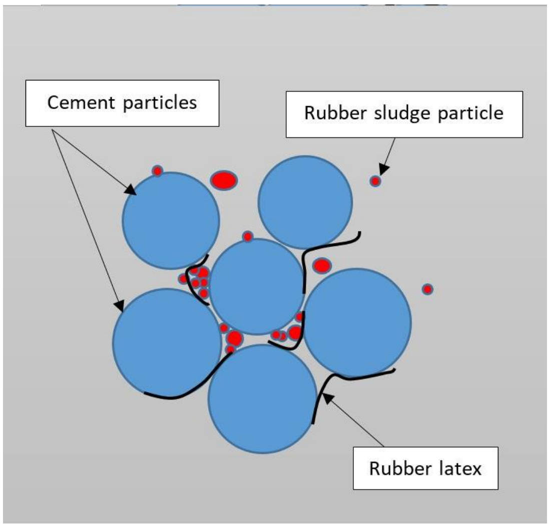
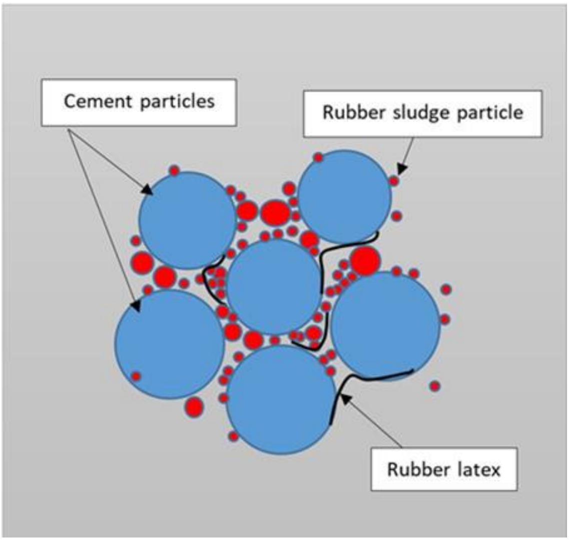


Fig. 1. The compressive strength development of high strength concrete containing concentrated latex and sludge.



(a)



(b)

Fig. 2. The stimulation pictures of concentrated latex and rubber sludge action on cement hydration reaction: (a) HRL0.5+RS2 and (b) HRL0.5+RS4

C. *The Tensile Strength Result*

The tensile strength result in Fig. 3 showed that, the control sample which was cured for 28 days gave 37.7 kg/cm^2 of tensile strength which was about 9.7 % compared to its compressive strength. The HRL1.0 and HRL0.5 samples respectively provided higher tensile strengths than the control one's. It was concluded that the para rubber latex played as an important particle in order to reduce a porosity inside the concrete. Since the high strength concrete had less porosity, it didn't need the latex much. Consequently, the result proved that 0.5% of latex replacement was a proper amount for improve the concrete tensile strength. It improved adhesion of cement molecules and aggregates as demonstrated in Fig. 4 (a). Oppositely, if it was replaced for 1.0%, it disturbed the hydration reaction of cement particles overwhelmingly by producing too many latex layers as shown in Fig 4 (b). Although latex layers in concrete could increase the strength but still the cement was the most important out of all ingredients. The result observation also confirmed that the 0.5% latex-concretes containing both 2.0% and 4.0% of sludge had obviously dropped their tensile strengths respectively. It happened the same way for the 1.0% latex-sludge concrete.

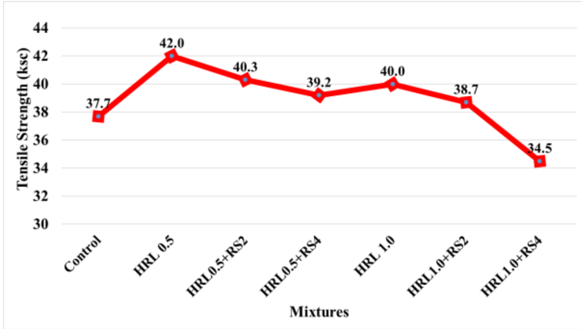
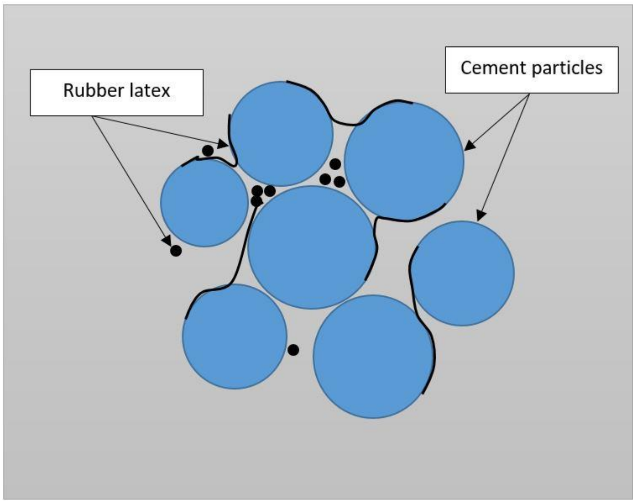
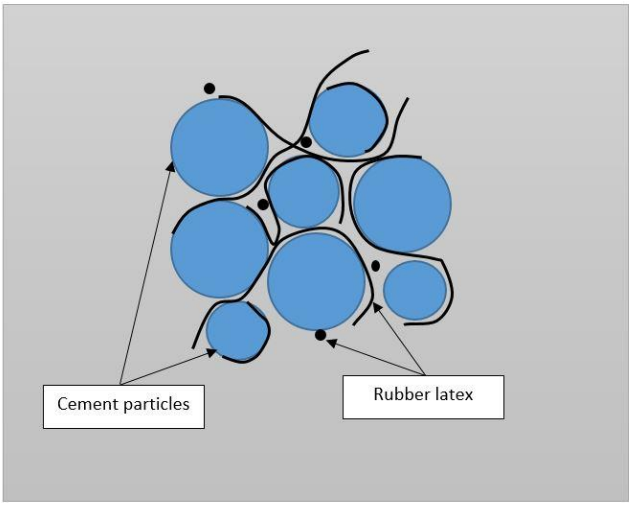


Fig. 3. The tensile strength result of high strength concrete containing concentrated latex and rubber sludge.



(a)



(b)

Fig. 4. The illustrated pictures of para rubber latex effect on the reaction of cement molecules: (a) HRL0.5 and (b) HRL1

Fig. 5. The inner surface of the latex-sludge concrete.

The Fig. 5 showed the inner surface of high strength concrete when there was excessive replacement of fine aggregate with rubber sludge. As the result, the sludge gathered together and became a distractor of concrete strength development.

IV. CONCLUSION

This research was conducted to observe and analyze the effects of the para rubber latex and sludge on the behaviors of high strength concrete namely workability, compressive strength and tensile strength. The conclusions were summarized as follows:

▪ The workability of high strength concrete reduced when it contained the latex and sludge. It mostly depended on the quantities of superplasticizer and rubber sludge while the latex did not affect much.

▪ The compressive strength of the latex-sludge concrete dramatically decreased when the latex and sludge replacements were increased.

▪ The 0.5% latex-concrete raised the best both compressive and tensile strengths. Yet, the strength of the latex-sludge concrete gradually went down when the replacement increased progressively.

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