

# Effects of Para Rubber Latex on Workability, Compressive Strength and Water Permeability of Normal Strength Concrete

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**Abstract.** *The objective of this research was to study the effects of para rubber latex on concrete properties even for fresh and hardened concrete namely; workability, compressive strength, and water permeability. LA-TZ, para rubber latex, was used as a partial water replacement at the rates of 0.5, 1.0, 1.5, and 2.0 percent by weight of water. The compressive strength of normal concrete was 24 MPa. The compressive strength of concrete samples was investigated at the ages of 3, 7, 14, and 28 days whereas only at the age of 28 days for water permeability test. The results showed that the para rubber latex reduced workability of fresh concrete but still in the acceptable range of design. The compressive strength increases in the mixtures containing of para rubber latex of 0.5, 1.0, and 1.5 percent by weight of water but dramatical decreases found in 2.0 mixture. The water permeability of para rubber latex concrete was related to its compressive strength, significantly. The concrete with replacement rate of 1.5 percent showed the compressive strength increase by 20 percent and the water permeability decrease by 60 percent comparing the control concrete.*

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## Keywords:

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## 1. Introduction

Thailand is the country that produces the world's highest of natural rubber or para rubber latex since 1990 with amount of 4.5 million tons in 2015 [1]. Over demand of para rubber latex was found in some years which resulted in price fluctuation. While the selling price is lower than the investment cost, then the economic crisis would be happened consequently. In 2017, the lowest ever of selling price of para rubber latex was happened. This was one of the biggest issues in Thailand in 2017. In order to solve this issue sustainably, Thai government supported and promoted

most researches and innovations that related in using of the over demanded para rubber latex. Construction industry is one of the highlight research in this field since it could consume a very high amount of para rubber usage for example the para soil cement for rural road [2]. Then, the price of the para rubber would be turned back to its reasonable price. In 2019, the Thai government set a plan to invest more than 2,000 million baht over 670 routes of para soil cement roads. However, the durability of this kind of road is still in issue since early defects were found in some routes. Therefore, research on using of para rubber latex for construction materials must be done urgently to learn more about para rubber latex, especially using in concrete works, the highest usage construction material in construction industry. Although, concrete has a high compressive strength as its major properties but its impervious behavior is quite low. Moreover, in a construction, concrete is always been used together with the reinforcing steel. Therefore, rusting by oxidation of reinforcing steel is still in an issue of using concrete structure especially in the severe areas such as coastal area, for example. Permeability of concrete depends directly on its compressive strength [3]. Then, using of pozzolanic materials in concrete is found more often in several researches [4-6]. However, concrete itself is a kind of composite material. Hence, increasing its impervious behavior may be done by using another impervious material to be combined in the mixture. There were few researchers found that para rubber latex could be used in concrete mixture [7-8] or even in soil mixture [9]. Although some properties of concrete were better such as water absorption and bending strength, however decreasing of compressive strength was usually found [7-8]. Using of para rubber latex in concrete needs more researches such as an optimum para rubber content that not reduces compressive strength and durability of concrete to improve concrete even better, especially for reducing of oxidation in reinforcing steel. The objective of this research is to study the effects of para rubber latex on concrete's workability, compressive strength, and water permeability. The results of this research would serve some important information of using para rubber latex in concrete works to decrease unnecessary issues in the future.

## 2. Materials

Portland cement type I was used through the research. The Low Ammonia-TMTD/ZnO type of concentrated para rubber latex (LA-TZ) was used as a partial replacement of water for every concrete mixture. To control the reliability, the commercial grade of the LA-TZ from an industry located in Rayong Province of Thailand has been selected and tested comparing to the ISO 2004: 2010 standard [10] and the results shown in Table 1. The results of using LA-TZ passes all values that specified in the ISO standard, then it could be

used confidently. Coarse aggregate with the maximum size of 3/4 inch and the specific gravity of 2.73 with the unit weight of 1550 kg/m<sup>3</sup> was used. While the fineness modulus and specific gravity of fine aggregate were 3.07 and 2.60, respectively. Both aggregates were roughly washed by water and air-dried under ambient condition to clear the fine particle away before using. The moisture contents of coarse aggregate and fine aggregate were 0.17 and 0.18 percent by weight, respectively. Those moisture contents will be used to obtain SSD-condition for both coarse and fine aggregates in design process.

Properties	Unit	Standard Value (ISO2004:2010)	Test result
Total Solid Content (Min.)	% by weight	61.0*	61.64
Dry Rubber Content (Min.)	% by weight	60.0	60.20
Non-Rubber Content (Max.)	% by weight	1.7	1.44
Alkalinity - on total weight (Max.)	%NH <sub>3</sub>	0.29	0.29
- on water phase	%NH <sub>3</sub>	-	0.76
pH Value at 25°C		-	10.04
KOH Number (Max.)		0.70*	0.57
Volatile Fatty Acid Number (Max.)	VFA No.	0.06*	0.0200
Mechanical Stability Time @55% TSC (Min.)	Seconds	650	900
Magnesium Content (on Solids)	ppm	-	25
Viscosity (Roto. No. 60 RPM)	cP	-	75
Color of Latex		-	White

\*The number shown in table could be used as it is or making a deal between buyer and seller

**Table 1** Properties of LA-TZ using in this research compared to the ISO standard values

Mixture	Cement	F.Agg	C.Agg	Water	Latex	W/C
Control	328.43	853.28	915.79	216.81	-	0.660
RL-0.5	328.43	853.28	915.79	215.73	1.08	0.657
RL-1.0	328.43	853.28	915.79	214.64	2.17	0.654
RL-1.5	328.43	853.28	915.79	213.56	3.25	0.650
RL-2.0	328.43	853.28	915.79	212.47	4.34	0.647

**Table 2** Mix proportions of para rubber latex concrete (kg/m<sup>3</sup>)

## 3. Experimental program

In this research, the designed compressive strength of concrete was 24 MPa at 28 days with the designed slump of 7.5 to 12.5 cm. The design procedure of concrete mixture followed the ACI 211.1-91 [11]. The LA-TZ was used as partial replacement of water for each concrete mixture. The replacement ratios were 0.0, 0.5, 1.0, 1.5, and 2.0 by weight of water, respectively. Slump of every fresh concretes was examined while mixing to observe its workability. Compressive strength of all mixtures would be observed at the ages of 3, 7, 14, and 28 days, respectively whereas the water permeability was investigated at the age of 28 days.

### 3.1 Material preparation

Commercial grade of Portland cement type I was used as received. Aggregates were washed by tap water before using to make sure that most fine particles were removed from the aggregates surface to prevent effects from very fine particle such silt and clay. For fine aggregate, after drying,

it was screened by passing a sieve no.4 and retained on a sieve no.100 whereas the coarse aggregate would be screened by using a sieve with opening of 1 inch and retained on a sieve no.4. The concentrated para rubber latex was used as received. Since, the para rubber latex was used as water replacement, it was mixed to water with specified ratios shown in Table 2 before mixing.

### 3.2 Mixing, molding and curing of specimens

Drum concrete mixer was used for all mixtures shown in Table 2. Coarse aggregate was the first ingredient filled in the mixer then followed by fine aggregate while the mixer was working. All aggregates were mixed in the mixer for 1 minute to make sure that the ingredients were whole distributed then added some amount of liquid ingredient. After 30 seconds, Portland cement was slowly added and followed by the left liquid ingredient, one after another, until

all ingredients were completely placed in the mixer. Continue mixing until all ingredients were mixed homogeneously by visual observation, the stop mixing. The whole mixing time was controlled to be not more than 5 minutes. Slump of fresh concrete was suddenly investigated after mixing following the ASTM C143/143M [12]. Afterward, the fresh concrete was placed in cylindrical molds having 10 cm in diameter and 20 cm in height. Fresh concrete was placed in mold by being separated to 3 layers and was tamped 25 times a layer. All fresh concrete samples, after molding, were left under an ambient condition for 24 hours, then demolded and cured fully submerged in water bath until the time of testing of each specimen comes. Molding, and curing methods were done by following the ASTM C31/31M [13].

### 3.3 Preparation of samples, testing, and calculation

Each mixture, the specimens was separated to 2 groups of testing. First is compressive strength test and the other is water permeability test. The specimens having 10 cm of diameter and 20 cm height as molded were directly used for compressive strength test, however, capping was applied. Each mixture, the compressive strength was the average value calculated by three samples. The test method followed the ASTM C 39/39M [14]. For water permeability test, the cylindrical specimens as molded were trimmed their top and bottom for 5 cm each side to avoid effects of paste and segregation, respectively. The rest, 10 cm height, of those specimens was cut at the middle to be used as 2 specimens of  $\phi 10 \times 4$  cm for the water permeability test, each mixture. Non-shrink epoxy resin was used to prevent the water leakage around the specimen's side and let water pass from top to bottom of the sample as shown in Fig.1 following the method found from Wongpa et al. [15]. The net flow rate taken from the test,  $Q$ , was used as a parameter in Darcy's law shown in equation 1.

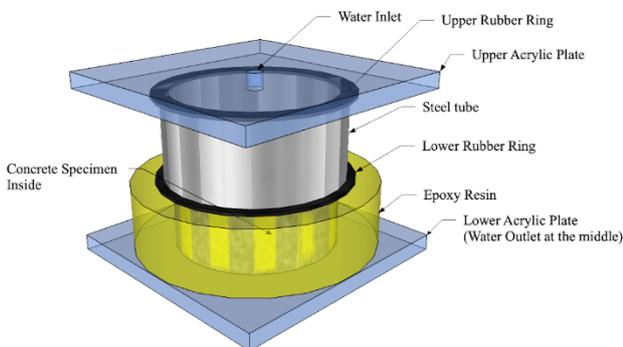


Fig. 1: Illustration of specimen installation for water permeability test

$$K_f = \frac{\rho L g Q}{P A} \tag{1}$$

where  $K_f$  is the coefficient of water permeability of the specimen (m/s),  $\rho$  is the density of water ( $\text{kg/m}^3$ ),  $L$  is the length of specimen (m),  $g$  is the gravitational acceleration ( $\text{m/s}^2$ ),  $Q$  is the net flow rate ( $\text{m}^3/\text{s}$ ),  $P$  is the water pressure (MPa) and  $A$  is the cross-sectional area of the specimen ( $\text{m}^2$ ).

## 4. Results and discussion

### 4.1 Effect of para rubber latex on workability of concrete

Slump is used as an evaluation method to measure workability of fresh concrete. Slump of each mixture is shown in Table 3. The control mixture was designed to obtain 24 MPa of compressive strength with 7.5-12.5 cm of slump. From the table, it was found that the slump of control mixture is 10.8 cm which in between the designed slump. For the mixtures containing para rubber latex, the observed slumps were decreased along the increasing of para rubber latex content, respectively. The lower slump of concrete containing para rubber latex was happened due to the latex particle that tried to make a polymer chain as usual. The polymer chain obstructed dissolution of cement by water, resulted in decreasing of slump. However, those slumps were in the range of designed slump. Adding of Para rubber latex as high as 2.0 percent by weight of water, the slump decreased for about 2.80 cm or about 25 percent. This could be implied that even the lower slump was found in mixture having para rubber latex significantly, however, the workability is still high enough for using as a normal concrete without issue in workability point of view. Fig. 2. shows the surface texture of RL-2.0 mixture. It was found that the specimen's skin was as smooth as the control mixture.

Mixture	Slump (cm)
Control	10.8
RL-0.5	9.8
RL-1.0	9.2
RL-1.5	8.5
RL-2.0	8.0

Table 3 Slump test results of para rubber latex concretes



Fig. 2: Surface of a testing specimen of RL-2.0

### 4.2 Effect of para rubber latex on compressive strength of concrete

The compressive strength results of para rubber latex concretes show in Fig. 3. It was found that the compressive strength increases along the increasing of latex content from 0.5 to 1.5 percent by weight of water. The maximum compressive strength at 28 days of the RL-1.5 is 31.5 MPa or about 20 percent higher than the control concrete at the same age. Moreover, its compressive strength is about 30 percent higher than that of the design strength. However, a dramatical decreasing of compressive strength was found in the RL-2.0 and lower than that of the control concrete as well. It means that the para rubber latex at the ratio of 2.0 by weight of water is too much or exceed the limitation for using in concrete. It might be that the latex content lower than 2.0 can distribute uniformly in concrete body. The latex particles might be located in several small pore structures of concrete after drying of water inside. Hence, it would not obstruct the reaction and bonding between cement particles after hydration. Whereas, the higher latex content, 2.0 namely, the latex particles bound to each other to make bigger latex particles. These particles flowed along the bigger size of water particle in concrete mixture due to adhesive force between latex and water. Bigger pore structures inside after all and leading lower compressive strength, consequently. Fig. 4 (a) and (b) show the illustrated assumption of pore structure after hydration process of mixtures those having latex content lower and higher than 2.0, respectively.

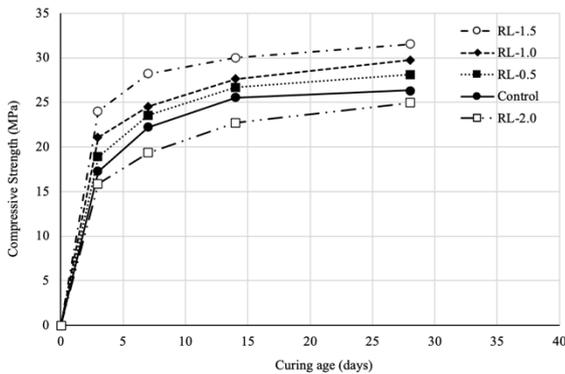
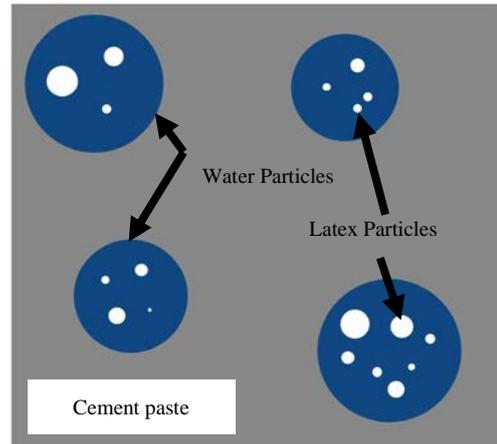
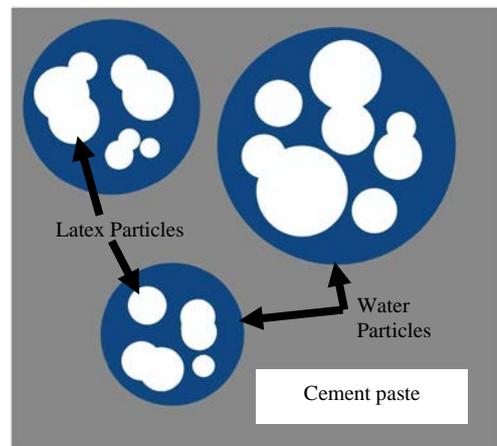


Fig. 3: Compressive strength development of para rubber latex concrete

Another assumption is that the exceed latex covers aggregates surface. Therefore, the latex obstructs bonding between aggregates and cement paste at interfacial transition zone and decreases bonding area as shown in Fig. 5. Therefore, lower compressive strength is observed.



(a)



(b)

Fig. 4: Pore structures of rubber latex concretes illustrated from assumption for concrete containing latex content (a) lower than 2.0 percent by weight of water (b) higher than 2.0 by weight of water

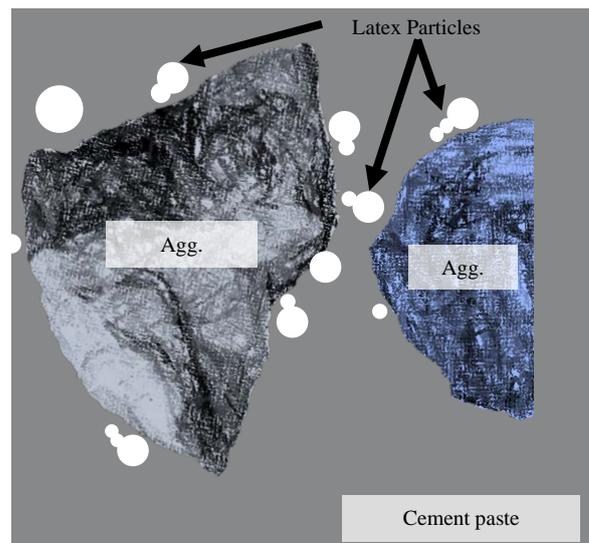


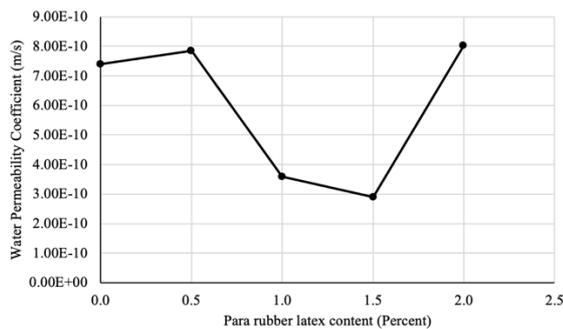
Fig. 5: Illustrated picture from the assumption that the exceed latex obstructs bonding at ITZ

### 4.3 Effect of para rubber latex on water permeability of concrete

The lowest water permeability of latex concrete, RL-1.5, is much lower than the control as shown in Table 4 and Fig. 6. Interestingly, adding of para rubber latex for only 1% could reduce the water permeability of concrete by half, approximately. In detail, it was found that increasing of para rubber latex content tends to decrease water permeability coefficient value as could be found in RL-0.5, RL-1.0 and RL-1.5, respectively. In addition, the highest increase of water permeability coefficient was found in RL-2.0. The highest water permeability is as high as 176.89 percent of the lowest one. Nevertheless, this value is similar to the control concrete and the RL-0.5 as well. The water permeability testing results seem having a relation to the compressive strength results especially the RL-1.5 that has the highest compressive strength and the lowest water permeability coefficient in this research. It might be that the latex particle inside voids reduce the overall void's space. Hence, the water permeability reduces, consequently. This reduce might be found in RL-2.0 as well. However, bigger voids happened due to bigger size of latex particle resulted in larger void's space. Therefore, increasing of water permeability found consequently and related to its compressive strength.

Mixture	Water Permeability Coefficient (m/s)
Control	7.40E-10
RL-0.5	7.85E-10
RL-1.0	3.58E-10
RL-1.5	2.90E-10
RL-2.0	8.03E-10

**Table 4** Water permeability test results of para rubber latex concrete



**Fig. 6:** Relationship between water permeability coefficient of concretes and latex contents

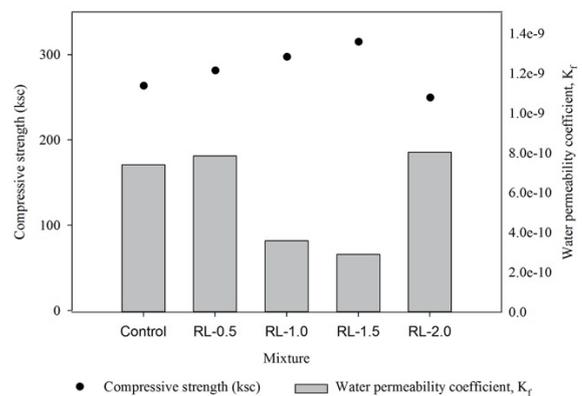
### 4.4 Relationship among compressive strength, water permeability coefficient, and para rubber latex content

Both compressive strength and water permeability coefficient of concrete at the age of 28 days are dependent on latex content as shown in Fig. 7. In addition, both parameters have a relation to each other, significantly. It was found that the higher compressive strength concrete such as

RL-1.0 and RL-1.5 have lower water permeability coefficient, obviously. Moreover, the latex concrete having similar compressive strength, similar water permeability coefficient would be found, for example the control concrete, RL-0.5, and RL-2.0. Possibly that the added latex would be placed itself into concrete's voids. These latex particles make the concrete denser due to filling the air voids. In addition, these latex particles would help supporting the void-structure from collapse. Therefore, higher impervious and higher compressive strength could be observed significantly. This relationship could be seen easily while comparing both compressive strength and water permeability coefficient to be plotted together as shown in Fig. 7. For RL-2.0, it shows suddenly lower compressive strength and higher water permeability coefficient comparing to the previous mixture namely RL-1.5. So, it is possible that latex content of 2.0 percent by weight of water is too much for using in concrete. The latex particles would be bound to each other and form a bigger and longer particle that could be seen by naked eyes from practice. These long-chain latex particles obstruct binding of cement paste and cause of bigger voids within concrete. Consequently, lower compressive strength and the higher water permeability coefficient would be observed. Therefore, it could be explained that the compressive strength and water permeability coefficient are related to each other significantly as described mechanism.

## 5. Conclusion

From the results it could be concluded that a suitable amount of para rubber latex could be used efficiently in concrete to enhance its compressive strength and impervious behavior of normal strength concrete, especially RL-1.5. Workability of fresh concrete containing latex might be decreased, however it is still in the range of required design slump. Compressive strength increases by 20 percent and water permeability coefficient decreases by 60 percent comparing to the control concrete.



**Fig. 7:** Relationship among compressive strength, water permeability coefficient and para rubber latex content of concrete at the age of 28 days

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## References

- [1] Thailand Board of Investment, Thailand: The world's leader in natural rubber production. *Thailand Investment Review*, 2016, vol. 26, no. 8, p. 3 – 4.
- [2] PAHUSUWANNO, S., INKLIANG, K., and HANHONGART, B. A study of para soil cement road construction (in Thai). *11<sup>th</sup> THAICID National Symposium*, Nonthaburi (Thailand), 2018, p. 265 – 276.
- [3] BU, J., and TIAN, ZH. Relationship between pore structure and compressive strength of concrete: Experiments and statistical modeling. *Sādhanā*, 2016, 14(3), p. 337 – 344.
- [4] Fajardo, G., Valdez, P., and Pacheco, J. Corrosion of steel rebar embedded in natural pozzolan based mortars exposed to chlorides. *Construction and Building Materials*, 2009, 23(2), p. 768 – 774.
- [5] Wang, Y., Tan, Y., Wang, Y., and Liu, C. Mechanical properties and chloride permeability of green concrete mixed with fly ash and coal gangue. *Construction and Building Materials*, 233, p. -.
- [6] Ahmet, R. B. and İlker, B. T. Influence of fly ash on corrosion resistance and chloride ion permeability of concrete. *Construction and Building Materials*, 2012, 31, p. 258 – 264.
- [7] Plangoen, P. Mechanical and physical properties of concrete modified with natural rubber latex. *5<sup>th</sup> Global Conference on Polymer and Composite Materials (PCM 2018)*, Kokura region, (Japan), 2018, p. -.
- [8] Palson, P., and Vidivelli, B. Mechanical properties of latex modified concrete with silica fume. *International Journal of Civil Engineering and Technology*, 2017, 8(9), p. 701 – 710.
- [9] Wongpa, J., and Thongsanitgarn. Effect of Para rubber latex and coir on compressive strength, water absorption and volumetric change of adobe brick. *International Journal of Agricultural Technology*, 2018, 14(7), p. 2229 – 2240.
- [10] ISO, Natural rubber latex concentrate – centrifuged or creamed, ammonia – preserved types – specifications. *International Standard ISO 2004 fifth edition*, 2010, p. 1 – 3.
- [11] ACI Committee 211. Standard practice for selecting proportions for normal, heavyweight, and mass concrete (ACI 211.1-91). *American Concrete Institute*, 2002.

- [12] ASTM International. ASTM C143/C143M-12: Standard test method for slump of hydraulic-cement concrete. *ASTM International*, 2012.
- [13] ASTM International. ASTM C31/C31M-08b: Standard practice for making and curing concrete test specimens in the field. *ASTM International*, 2008.
- [14] ASTM International. ASTM C39/C39M-14: Standard test method for compressive strength of cylindrical concrete specimens. *ASTM International*, 2014.
- [15] Wongpa, J., Kiattikomol, K., Jaturapitakkul, C., Chindaprasirt, P. Compressive strength, modulus of elasticity, and water permeability of inorganic polymer concrete. *Materials and Design*, 2010, 31(10), p. 4748 – 4754.

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