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Compressive and Splitting Tensile Strength of Polymer Modified Concrete Using Amylum and Honey

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Abstract: Polymer modified mortar and concrete are innovation of concrete that provide better characteristics of bond strength, freezing-and thawing resistance, abrasion resistance, flexural and tensile strengths, permeability and elastic modulus. Previous researches have proven that natural polymer modified concrete achieved high compressive strength and durability. This research wanted to investigate compressive and splitting tensile strength of polymer modified concrete using amylum and honey. The polymer modified concrete has compressive strength design of f'_c = 30 MPa . There were 3 categories and 24 compositions for each category, A-F and control specimens. Compressive test was conducted at ages 7, 14 and 28 days while splitting tensile test at age 28 days. The result met conclusions that optimum composition of polymer modified concrete with amylum and honey for best performance of compressive and splitting tensile strength achieved by category 2 on specimen KT-0.03-G and also amylum and honey provide good bond mechanism and compactness for natural polymer modified concrete.

Key words: Compressive strength, splitting tensile strength, natural polymer modified mortar, amylum, honey, concrete

INTRODUCTION

Concrete is the most famous material used in building construction around the world. However, it has limitation on durability, tensile strength, drying shrinkage, hardening and chemical resistance (Ohama, 1995). It was investigated that concrete strength and performance depend on its curing conditions and also external and internal chemical ingredients such as salt and sulphate. Hence, several innovation have been introduced to get better performance of concrete, one is the production of polymer concrete. The main idea of polymer concrete innovation is to improve concrete performance by adding polymer modifiers. There is an important category of polymer concrete, it is Polymer-modified Cementitious Mixtures (PCM) that includes polymer modified mortar and polymer modified concrete. PCM can be defined as hydraulic cement combined at the time of mixing with organic polymers that are dispersed or redispersed in water with or without aggregates (Anonymous, 2003). The polymer modified mortar and concrete can also made by partially replacing the hydraulic cement with polymers (Ohama, 1995). The wide using of polymer modified mortar and concrete is remarked as good performance of bond strength, freezing-and thawing resistance, abrasion resistance, flexural and tensile strengths, permeability and elastic modulus (Anonymous, 2003).

The use of natural or organic polymers into concrete and mortar mix has been known, since, ancient period (Babylonia, Mohenjo-daro and Harappa and China) until modern time (several patents for natural and synthetic polymers). Previous researches also reported about the advantage of polymer modified concrete and mortar using *Euchema cotonii, Gracilaria* Sp., *Moringa oleifera* and honey (Susilorini *et al*., 2014; 2015a-c; 2017a, b). There were also several studies about starch (corn, maize, tapioca) application into concrete (Akindahunsi *et al*., 2012; Joseph and Xavier, 2016) as well as sticky rice (Yang *et al*., 2010), gram-flour, ghee and triphala (Patel and Deo, 2016a, b). Those researches emphasized that carbohydrate polymers and any other natural polymers improved the performance of concrete and can be used as eco-friendly materials. This research tries to address an innovation made by adding carbohydrate polymer and honey to get better performance of concrete.

Among natural carbohydrate polymers, corn starch is used frequently to enrich concrete performance. However, there is a good reason to use another

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carbohydrate polymer such as rice flour because it has advantages that may improve the durability of concrete. Rice (*Oryza sativa* L.) is consumed around the world, where Asian people take it as staple food. Most people consumed rice as cooked polished grains and used rice flour as an ingredient in cuisines. Immaningsih (2012) reported that rice flour is rich of carbohydrates (80.30%) and also starch (67.68%) where the starch consists of amylose (11.78%) and amylopectin (88.22%). Several investigations emphasized the advantages of rice flour. Rice flour has high peak viscosity and high gelatinization enthalpy caused by milling process (Leewatchararongjaroen and Anuntagool, 2016) and also high amylase content (Anugrahati *et al*., 2017) but it takes time long enough to achieve the peak viscosity, even though it will remain steady at cold temperature (Imanningsih, 2012).

It was proven honey can improve the performance of concrete (Susilorini *et al*., 2015a-c). Honey is original sweetener produced by nature and also supersaturated sugar solution (Ball, 2007). Honey composition depends on its floral source, seasonal and environmental factors (Tudjono *et al*., 2014). Major compounds of honey are fructose (about 38.4%) and glucose (about 30.3%) and also other compounds such as acids and minerals (Ball, 2007). Previous research reported that honey (alone and also used together with *Gracilaria* Sp.) can improved compressive strength of polymer modified mortar and concrete (Susilorini *et al*., 2015a-c) because the increase bond mechanism. In this research, amylum as carbohydrate polymer and honey were added into concrete mix to enrich concrete performance. The using amylum and honey for polymer modified concrete compressive and splitting tensile strength will be investigated in this research.

MATERIALS AND METHODS

This research conducted experimentally by producing concrete cylinder specimens for compressive strength test (Fig. 1) and splitting tensile strength test (Fig. 2). The natural polymers used were amylum from rice flour and honey. Natural polymer modified concrete has compressive strength design of f'_c = 30 MPa, w/c = 0.45 and slump = ±10 cm. There were 3 categories and 24 compositions of natural polymer modified concrete, A-F, for compressive and splitting tensile strength test, plus one category of control as described by Table 1. Specimens for compressive strength test were cylinders with dimension of 10×20 cm while specimens for splitting tensile test were 15×30 cm. Specimens for compressive strength test were tested at ages 7, 14 and 28 days while specimens for splitting tensile test were tested at age 28 days. Testing for compressive strength based on ASTM C39/C39M-03 while splitting tensile test based on C496/C496M-11.

Table 1: Compositions of polymer modified concrete with amylum and honey

		Honey	Amylum
Categories	Specimen code	(Cement weight %)	
Control	Control	0 (%)	0 (%)
1	KT-0-A/KTB-0-A	0	0.10
	KT-0-B/KTB-0-B		0.20
	KT-0-C/KTB-0-C		0.50
	KT-0-D/KTB-0-D		1.00
	KT-0-E/KTB-0-E		2.00
	KT-0-F/KTB-0-F		5.00
2	KT-0,03-G/KTB-0,03-G	0.03	0.10
	KT-0,03-H/KTB-0,03-H		0.20
	KT-0,03-I/KTB-0,03-I		0.50
	KT-0,03-J/KTB-0,03-J		1.00
	KT-0,03-K/KTB-0,03-K		2.00
	KT-0,03-L/KTB-0,03-L		5.00
3	KT-0,3-M/KTB-0,3-M	0.30	0.10
	KT-0,3-N/KTB-0,3-N		0.20
	KT-0,3-O/KTB-0,3-O		0.50
	KT-0,3-P/KTB-0,3-P		1.00
	KT-0,3-Q/KTB-0,3-		2.00
	KT-0,3-R/KTB-0,3-R		5.00

Fig. 1: Set-up of compressive strength test

Fig. 2: Set-up of splitting tensile strength test

RESULTS AND DISCUSSION

The experiment results found some interesting points of view. For control specimens, compressive strength design of 30 MPa was achieved. At 28 days, control specimens compressive strength was 31.34 MPa as described by Table 2 and 3. Gradual compressive strength has increased from 4-28 days from 26.24-31.34 MPa. The splitting tensile strength is 12.05% of 28 days compressive strength.

In general, compressive strength of specimens was varying at all ages as described by Fig. 3. For age 7 days, category 1 and 2 were varying from 18.85-29.04 MPa. For category 2 (0.03% honey of cement weight), compressive strength was more fluctuating compared to category 1 (0% honey of cement weight). It should be noted that in category 3 (0.3% honey of cement weight), the compressive strength were getting lower extremely from 18.60-1.53 MPa. Control specimens compressive strength at age 7 days were mostly higher (26.24 MPa) compared to all categories. It was only KT-0.03-G that achieved 29.04 MPa which was higher than control specimens at 7 days.

Figure 3 describes that at age 14 days, category 1 achieved about similar compressive strength that was varying from 22.93-31.34 MPa. Category 2 had compressive strength about 23-24 MPa and there was only one specimen achieving 29.72 MPa. It is also shown by Fig. 3 that compressive strength of category 3 is fluctuating from 20.13-32.10 MPa. Compared to control specimens at age 14 days, there were only 3 specimens that had higher compressive strength (KT-0-B, KT-0.3-M and KT-0.3-P).

It is interesting to find the result at age 28 days. Figure 3 has shown that there were only 4 specimens (KT-0.03-G, KT-0.03-I, KT-0.03-I and KT-0.3-N) had higher compressive strength compared to control specimens and 3 specimens (KT-0.03-H, KT-0.03-L and KT-0.3-N) had about similar to control specimens. All specimens of category 1 had lower compressive strength compared to the control specimens while category 3 only had one specimen achieved higher compressive strength compared to control specimens. It was noted that all specimens of category 2 had higher category 3 only had one specimen that achieved higher compressive strength compared to control specimens.

Those result mentioned above is very interesting. For compressive strength results (Fig. 1) 29.17% specimens have lost their compressive strength at age 28 days (KT-0-B, KT-0-C, KT-0-D, KT-0-E, KT-0-F, KT-0.3-M and KT-0.3-O), despite of their increase compressive strength from 7-14 days. Optimum compressive strength achieved by specimens KT-0.03-G, KT-0.03-I, KT-0.03-J and KT-0.3-N. These specimens have compressive strength exceed 30 MPa and gradual increase of compressive strength.

The experiment result also noted splitting tensile strength performance at age 28 days of those specimens mentioned above (Fig. 4). It was seemed that most specimens splitting tensile strength in all categories laid under the control specimens (3.77 MPa). There were only

Table 2: Experimental result for control specimens

Type of test	Strength (MPa)
Compressive strength (days)	
7	26.24
14	29.72
28	31.34
Splitting tensile strength	
28	3.77

Table 3: Equations and R^2 for splitting tensile strength and compressive strength relationship

Category	Equation	R^2
1	$y = -0.390x+12.540$	0.959
2	$y = 0.029x+2.551$	0.978
3	$y = 0.047x+1.667$	0.999

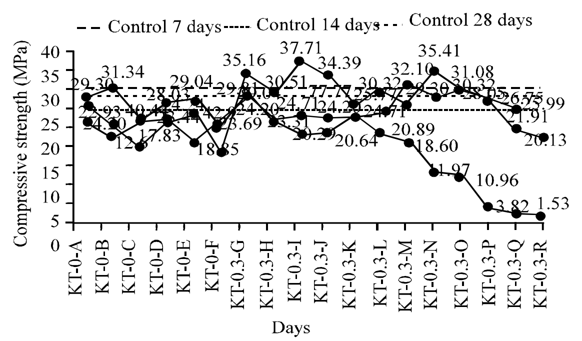

Fig. 3: Compressive strength of specimens and controls at ages 7, 14 and 28 days (Susilorini *et al*., 2017a, b)

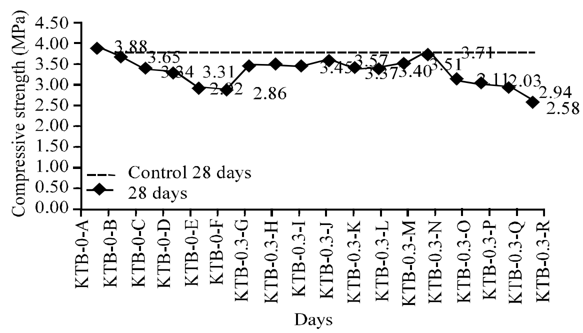

Fig. 4: Splitting tensile strength of specimens (Susilorini *et al*., 2017a, b)

two specimens achieved splitting tensile test higher than control specimens, KT-0-A (3.88 MPa) and KTB-0.3-N (3.71 MPa). For category 1, the splitting tensile strength was getting lower from 3.88-2.86 MPa. It was found that category 2 had constant value of splitting tensile strength about 3.37-3.57 MPa. The splitting tensile strength for category 3 was fluctuating from 2.58-3.71 MPa.

Based on Fig. 3 and 4, the splitting tensile strength value can be determined in percentage as shown by Fig. 5. It was described by Fig. 5, that splitting tensile strength of specimens were varing from 9.91-18.73% of compressive strength. Category 1 still performed fluctuating value while category 2 little bit varying and category 3 was much more stable.

After observing the percentage of splitting tensile strength of compression strength (Fig. 5) each category was analyzed for regression to find their equations and R^2 as described by Fig. 6 and Table 2. It was observed by Fig. 6 that category 2 had best performance of splitting tensile strength and compressive strength relationship, because both parameters were higher compared to other categories. All categories have good R^2 values, close to 1 (from 0.959-0.999). The three equations from all categories then being used in Fig. 7 for relationship of splitting tensile strength percentage and compressive strength of all categories which compared to the one of ACI 318-14.

Further result analysis was comparing the relationship of splitting tensile strength percentage and compressive strength between experimental results and analytical result of ACI 318-14. Relationship of splitting tensile strength percentage and compressive strength of ACI 318-14 (Al-Sahawneh, 2015) may be defined by Eq. 1 as follow:

$$fct = 0.56\,\lambda\,(f'_c)^{0.5} \quad (1)$$

Where:

f_{ct} = Splitting tensile strength
λ = factor = 1 for normal weight concrete
f'_c = Compressive strength

Figure 7 has shown that the relationship of splitting tensile strength of category 1 was jumped over the reference (result of ACI 318-14) about 70% higher. Category 2 had similar relationship of splitting tensile strength to the reference while category 3 was just about 30% lower compared to the reference. The experiment results emphasized that amylum and honey has given great contribution for compressive strength increase. Amylum of rice fluor has high peak viscosity and high gelatinization while honey contains fructose and sucrose which enrich bonding mechanism of concrete. Hence, category 2 and 3 performed (that used 0.03 and 0.3% honey of cement weight) better performance compared to category 1 (that used 0% honey of cement weight). It was interesting that for all categories, the addition of amylum beyond 0.5% of cement weight will reduce compressive strength (Fig. 3). The addition of honey has made distinction to compressive and splitting tensile test in all categories. For category 1, there was no honey addition

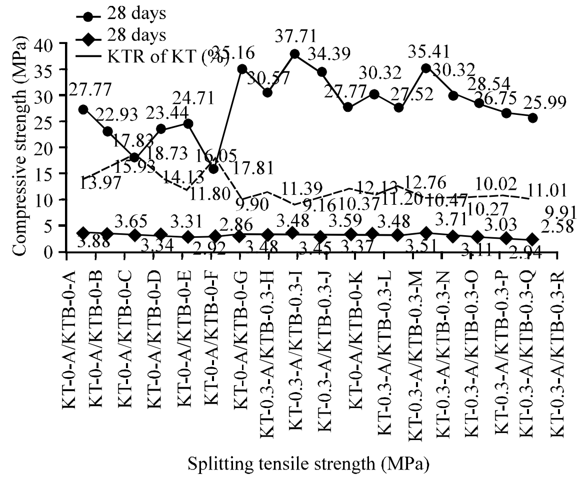

Fig. 5: Splitting tensile strength percentage of compressive strength of specimens

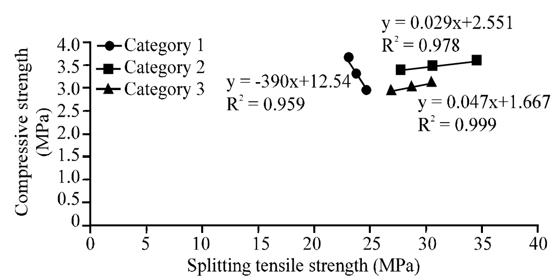

Fig. 6:. Regression of splitting tensile strength and compressive strength relationship

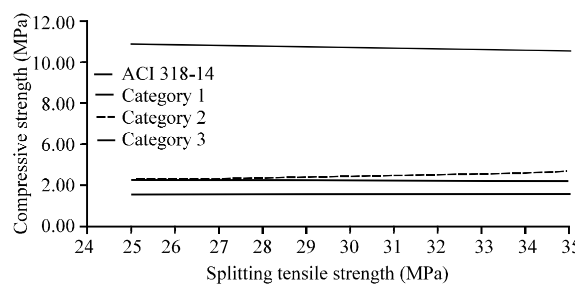

Fig. 7: Comparison of relationship of splitting tensile strength percentage and compressive strength between ACI 318-14 and all categories

(0% honey of cement weight), hence, the development of compressive strength from 0-7 and 14 days was good. But the addition of amylum without honey for category 1 has rolled down its compressive strength at age 28 days, even lower than its compressive strength at age 7 days for addition exceed 0.10% of cement weight (Fig. 3). It was not happened to category 2, that addition of 0.03% honey of cement weight even gave good development of compressive strength from 0-7, 14 and 28 days. Delay of compressive strength development was happened at age 0-7 days for category 3 that has 0.3% honey of cement weight. The value of compressive strength of category 3 at age 7 days was very low that may caused by the high peak viscosity and high gelatinization of honey.

The optimum composition between amylum and honey will contribute to splitting tensile strength achievement as shown by Fig. 4. When category 1 only had amylum addition and no honey addition, its splitting tensile strength was getting down. The splitting tensile strength was also getting down with addition of amylum and honey with high concentration (0.3% of cement weight). It was not happened to category 2 that splitting tensile strength performed stable because of optimum composition of amylum and honey with low concentration (0.03% of cement weight).

This research found that optimum composition of polymer modified concrete with amylum and honey for best performance of compressive and splitting tensile strength is category 2 on specimen KT-0.03-G. This specimen produced by low concentration of (0.1% of cement weight) amylum and honey (0.03% of cement weight) but achieved high compressive strength (35.16 MPa) and splitting tensile strength (3.48 MPa).

CONCLUSION

This research has met conclusions: Control specimens compressive strength (26.24 MPa) at age 7 days were higher compared to all categories; There were only 3 specimens of category 1 and category 3 that achieved higher compressive strength (KT-0-B, KT-0.3-M and KT-0.3-P) compared to control specimens (29.72 MPa); There were only 4 specimens (KT-0.03-G, KT-0.03-I, KT-0.03-I and KT-0.3-N) had higher compressive strength compared to control specimens (31.34 MPa) and 3 specimens (KT-0.03-H, KT-0.03-L and KT-0.3-N) had about similar to control specimens; There were only two specimens achieved splitting tensile test higher than control specimens, KT-0-A (3.88 MPa) and KTB-0.3-N (3.71 MPa); Splitting tensile strength of specimens were varing from 9.91-18.73% of compressive strength; Category 2 had similar relationship of splitting tensile strength to the reference of ACI 318-14; Optimum composition of polymer modified concrete with amylum and honey for best performance of compressive and splitting tensile strength is category 2 on specimen KT-0, 03-G and Amylum and honey provide good bond mechanism and compactness for natural polymer modified concrete.

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