

Properties of concrete using crumb rubber and rice husk ash as additive for rigid pavement material in peat environment

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Abstract. A waste tyre is an inorganic rubber waste that is difficult to decompose since it has a complex structure. Utilization of waste tyre as a material to improve elastic properties in rigid pavement construction in peat environment has not investigated yet. The rigid pavement in peat environment needs to be impermeable and posses high elastic properties. This paper presents mechanical properties and porosity of concrete incorporating crumb rubber as an additive in concrete mixture with a variation of 10%, 20%, and 30% by fine aggregates volume. Rice husk ash is added as a filler in various percentage (5%, 10%, and 15%) by cement volume in the mixture. Concrete is produced with a target strength of 35 MPa. In this research, the OPC concrete mix is used as a control mix. Mechanical properties taken were the compressive strength, tensile strength, flexural strength, modulus of elasticity, and porosity at 7, 14 and 28 days. Results show that crumb rubber and rice husk ash addition increases compressive strength, improves elastic properties, i.e., tensile strength, flexural strength, modulus of elasticity, and reduce the porosity of the concrete. It can be concluded that the crumb rubber is potential as an environmentally friendly additive as rigid pavement material in peat environment.

1 Introduction

A waste tire is an inorganic waste from vehicles that are difficult to decompose since it has a complex structure. Destruction by burning will also be difficult because it requires temperatures above 322°C [1]. Based on statistical data from the Central Bureau of Statistics (BPS), in 2013 the total amount of vehicles in Indonesia reaches 104,118,969 unit and increase to 114,209,266 unit in 2014 [2]. The number continues to grow, requiring a breakthrough to solve this waste tire problem.

Concrete is still widely used in construction since it has high compressive strength, easy processed, and economical in manufacturing and maintenance process, but there is a lack of concrete which has low flexural strength so fine cracks are often formed around the concrete. The use of waste tire in the form of crumb rubber to increase the flexibility and

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prevent cracking of concrete is rated suitable since it has a quite high modulus of elasticity value at 0.77 to 1.13 MPa and low-density value at 1.08 to 1.27 t/m³ [3].

Along with the increasing flexural strength of concrete with a mixture of used crumb rubber, the compressive strength of the concrete will also increase because the presence of fiber in concrete give reinforcement to concrete. However, after reaching optimal content, the concrete will experience a decrease in compressive strength because the addition of crumb rubber is considered to reduce the density of the concrete mix so that the concrete mixture will not compress properly [4, 5]. The additional material is needed to minimize the decrease in the compressive strength of the concrete.

Rice husk burning produces rice husk ash containing chemical compounds in the form of silica. The content of silica in the concrete mixture will increase the compressive strength and reduce the porosity of the concrete [6]. Addition of rice husk ash also increases the tightness of the concrete mix so that the combination of crumb rubber with rice husk ash is rated suitable for producing flexible concrete with high compressive strength.

Concrete characteristics with crumb rubber and husk ash as described above have the potential to be used as a construction material on peat environment. Peatland is acidic and potentially deteriorate mortar and concrete that is solely using Ordinary Portland Cement as a binder after 28 days exposed to the environment [7, 8]. Concrete that exposed directly to peat water for example rigid pavement needs to pay attention to the resistance of the structure. Cracks caused by changes in temperature, vibration, and other causes can be minimized by increasing the flexural strength of the concrete and the value of its resistance so that acidic peat water will not penetrate the concrete and causes damage to concrete or steel in the rigid pavement.

2 Materials and methods

In this research, the concrete specimens were manufactured using Ordinary Portland Cement (OPC), aggregates, crumb rubber, rice husk ash (RHA), and water. Coarse aggregates had a specific gravity of 2.59 and water absorption of 0.28%. Fine aggregates had a specific gravity of 2.55, fineness modulus of 3.35, and water absorption of 3.62%. In order to obtain the optimum addition, crumb rubbers sized 0.075-4.75 mm were added in the concrete mixture with variation 10%, 20%, 30% by fine aggregates volume and RHA were added with variation 5%, 10%, 15% by cement volume. The optimum addition of 30% crumb rubber and 10% RHA is obtained from the compressive strength test of 105x210mm cylinders and used to investigate the mechanical properties of the rubber concrete. The specimens were given a code according to the variation applied for mixing; for example, 10/5 denotes concrete mixed with 10% crumb rubber and 5% RHA. Table 1 shows the mixture composition for optimum addition.

The rubber concrete was designed to have a target compressive strength of 35 MPa. The mixture composition of OPC concrete per m³ consisted of coarse aggregates (923.32 kg), fine aggregates (686.91 kg), cement (500 kg), and water (208.77 kg) with the addition of crumb rubber (32.50 kg) and RHA (67.92 kg) for OPC rubber. The specimens were cast in 150x150x150mm cubes for compressive strength, 150x300mm cylinders for splitting tensile strength and Modulus of Elasticity, 150x150x600mm for flexural strength. Normal and rubber concrete was cured up to 28 days at water pond and were made to determine the mechanical properties by conducting tests for compressive strength (SNI 03-1974-2011), splitting tensile strength (SNI 03-2491-2002), flexural strength (SNI 03-4431-2011), porosity (ASTM C642), and modulus of elasticity (ASTM C469) of OPC and OPC rubber concrete at 7, 14 and 28 days.

Table 1. The mixture composition for optimum addition.

Mixes	Coarse agg. (kg)	Fine agg. (kg)	Cement (kg)	Water (kg)	Rubber (kg)	RHA (kg)
20/5	6.04	4.50	3.27	1.39	0.14	0.22
20/10	6.04	4.50	3.27	1.40	0.14	0.44
20/15	6.04	4.50	3.27	1.42	0.14	0.66
10/10	6.04	4.50	3.27	1.40	0.07	0.44
30/10	6.04	4.50	3.27	1.40	0.21	0.44

3 Results and discussion

3.1 Compressive Strength

Compressive strength was used to obtain the optimum addition of crumb rubber and RHA in the concrete mixture with a target strength of 25 MPa. Table 2 shows the compressive strength of concrete with the addition of crumb rubber and RHA at 7, 14, and 28 days. The optimum mixture was the mixture with 30% crumb rubber and 10% RHA which has the highest strength of 26.56 MPa at 28 days. Subsequently, the optimum mix was used to study the mechanical properties of the OPC rubber.

Table 2. Compressive strength of concrete with addition of crumb rubber and RHA.

Mixes	Compressive strength (MPa)		
	7 days	14 days	28 days
20/5	16.75	23.10	24.25
20/10	18.48	23.10	24.25
20/15	15.01	20.79	23.10
10/10	15.59	21.36	25.41
30/10	19.63	24.83	26.56

Table 3. Compressive strength of OPC and OPC rubber.

Mixes	Compressive strength (MPa)		
	7 days	14 days	28 days
OPC	32.22	36.89	40.00
OPC rubber	23.11	27.11	36.22

The mixture was re-designed with optimum mix of crumb rubber and rice husk ash to obtain target strength of 35 MPa. The compressive strength of OPC and OPC rubber using 30% crumb rubber and 10% RHA is shown in Table 3. In general, the compressive strength of both types of concrete at 7, 14, and 28 days has increased, as shown in Fig. 1.

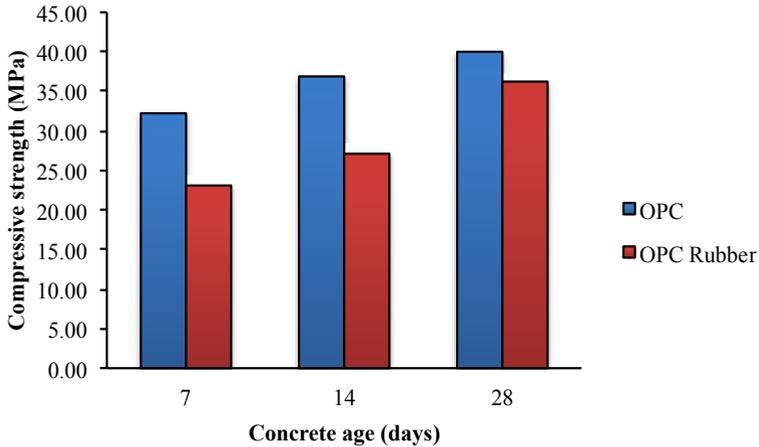


Fig. 1. Variation of compressive strength of OPC and OPC Rubber with concrete age.

The OPC rubber showed a lower strength than the OPC concrete. This was likely due to the high content of the crumb rubber and decrease adhesion between the surface of rubber particles and cement paste. As the crumb rubber content increased in the concrete, the strength properties decreased significantly [5]. The decrease in compressive strength was also due to lower stiffness of crumb rubber particles. This finding was supported by Bisht et al. [9]. However, the compressive strength of OPC rubber increases significantly at 28 days as a result is 36.22 MPa, probably due to the effect of cementitious material or RHA used in the mixture. It was reported that cementitious material was used for the rubberized concrete mixture to improve interfacial transition zone (ITZ) and subsequently the mechanical bond of concrete [10, 11].

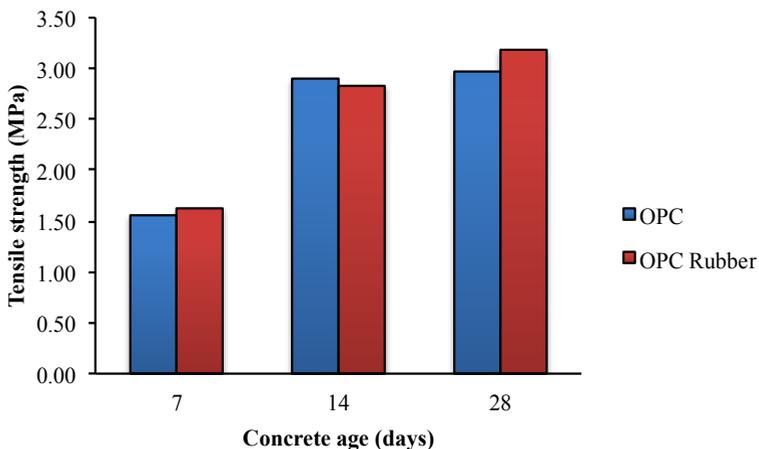


Fig. 2. Variation of tensile strength of OPC and OPC Rubber with concrete age.

3.2 Tensile strength

Fig. 2 displays the splitting tensile strength of OPC and OPC rubber at 7, 14, and 28 days. It shows that there was a gradual increase in tensile strength for both types of concrete. However, the test result comes in varies. At the age of 7 days, OPC rubber had the slightly higher strength then OPC but got lower at 14 days. The tensile strength of OPC rubber risen significantly at 28 days. This result was likely due to an improved bonding between the aggregates and cement paste.

3.3 Flexural strength

The flexural strength of OPC and OPC rubber at 7, 14, 28 days is shown in Fig. 3. It can be seen that the flexural strength for both types of concrete increase gradually. Since the early ages, OPC rubber has a flexural strength that higher than OPC. The highest value of flexural strength was shown by OPC rubber at 28 days, while the OPC showed the lowest value. The influence of crumb rubber on concrete mixture could increase the flexural strength of concrete. This was likely due to the elasticity of crumb rubber that capable of bearing load so that concrete will not easily be broken. The higher value of flexural strength used to prevent the formation of fine cracks that could cause damage from outside attacks such as acid in the peat area. According to SNI T14-2003, the concrete quality for rigid pavement must satisfy the values of 3-5 MPa at 28 days. In this research, the flexural strength of OPC Rubber was 3.18 and complied with the SNI T14-2003.

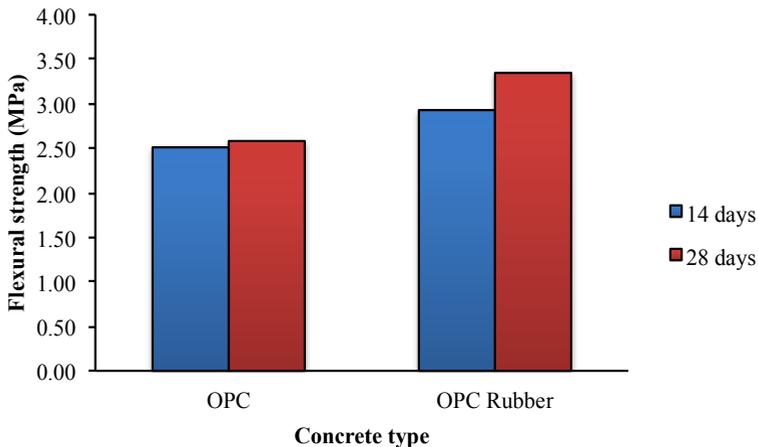


Fig. 3. Variation of flexural strength of OPC and OPC Rubber with concrete type.

3.4 Modulus of elasticity

Based on results of testing the modulus elasticity that shown in Fig. 4, it was found that the addition of crumb rubber and husk ash in the concrete mixture was able to increase the modulus elasticity from 26,211.49 MPa to 27,591.03 MPa at the age of 14 days and from 25,244.08 MPa to 27,509.86 MPa at 28 days. The increase is caused by crumb rubber that acts as a fiber in the concrete and used to increase the resistance from straining when concrete receives the load.

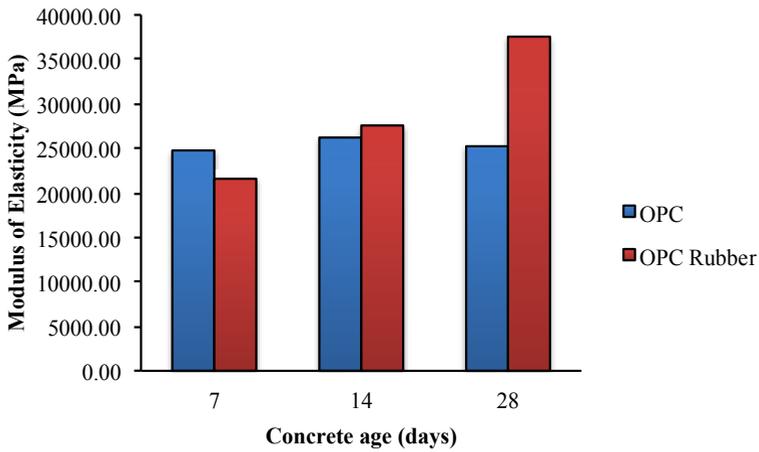


Fig. 4. Variation of Modulus of Elasticity of OPC and OPC Rubber with concrete age.

3.5 Porosity

The porosity of OPC and OPC rubber at 7, 14, and 28 days is shown in Fig. 5. It can be seen that the porosity of OPC rubber has a lower value than the OPC concrete at 7, 14, and 28 days. This is due to the filling of pores or space in concrete by crumb rubber and RHA. Incorporating cementitious material for concrete in peat acid could reduce porosity as reported by Olivia et al. [8]. Decreasing porosity makes OPC rubber concrete denser and more impermeable so that it has better resistance than OPC concrete from extreme environmental conditions, such as acid in the peat environment.

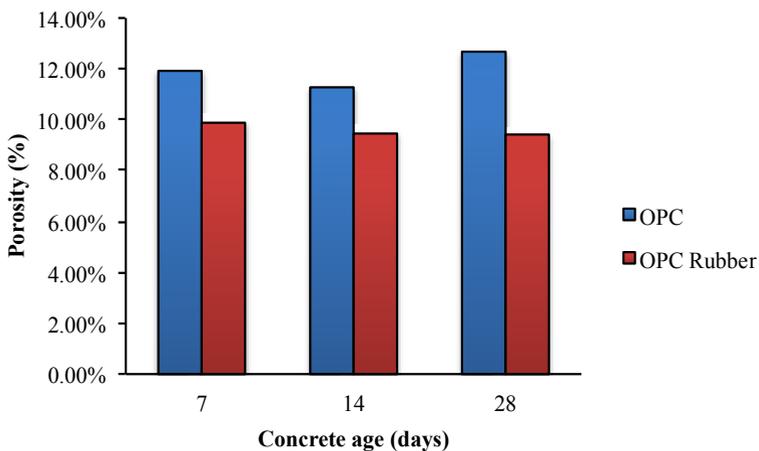


Fig. 5. Variation of porosity of OPC and OPC Rubber with concrete age.

4 Conclusions

Crumb rubber and RHA was added to the OPC concrete to improve the mechanical properties of the concrete. It was found that the addition of crumb rubber and RHA tend to

reduce compressive strength and porosity of the OPC rubber. The mechanical properties such as tensile, flexural and modulus of elasticity of OPC Rubber were slightly higher than the OPC concrete. It can be concluded that the OPC rubber incorporating RHA has relatively better properties than those of OPC concrete as a rigid pavement material in peat environment.

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