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USING RUBBER AGGREGATE DERIVED FROM DISCARDED TIRES FOR PRODUCING CEMENT CONCRETE TOWARDS RESOURCE RECOVERY AND ENVIRONMENTAL PROTECTION IN VIETNAM

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ABSTRACT

This study aims to explore the possibility to use rubber particles derived from discarded tire as aggregates for replacing fine and coarse natural aggregates to produce cement concrete towards resource recovery and environmental protection in Vietnam. The experimental results showed that the workability of fresh rubberized concrete was improved when replacing natural fine aggregate (sand) with fine rubber particles (2.5-5 mm) at the replacing proportions of 30-50% by volume, and when replacing natural coarse aggregate (crushed stone) with coarse rubber particles (5-20 mm) at the replacing proportions of 10-30% by volume. With respect to the mechanical properties of hardened rubberized concrete, a larger reduction in the compressive and flexural strengths was generally found when the replacing proportions increased and when coarse aggregate rather than fine aggregate was replaced by rubber particles at all replacing proportions. However, the study results also indicated that using fine rubber particles for replacing fine natural aggregate at the low replacing proportion (up to 10%) might not cause the significant effect on the compressive and flexural strength of rubberized concrete.

Contribution/Originality: This is the first ever study in Vietnam to investigate the potential for using rubber particles derived from discarded tires to replace natural aggregates in producing cement concrete towards resource recovery and environmental protection in Vietnam.

1. INTRODUCTION

It has been estimated that 1000 million tires reach the end of their useful life every year. By the year 2030, the number can reach up to 1200 million tires representing almost 5000 million tires (including stock piled) to be discarded on a regular basis (Pacheco-Torgal *et al.*, 2012). The development and enforcement of regulations and guidance on collection, storage and separation, transport, processing, disposal, and recycling activities for discarded tires in several countries such as USA, Japan, Korea, and Taiwan has brought a number of environmental and economic benefits in those countries (Jang *et al.*, 1998). However, in many developing countries including Vietnam, there are lacking of such regulations and guidance in place. In these countries, discarded tires have been largely treated in unsustainable manners. At present, enormous quantities of discarded tires are already stockpiled (whole tire as shown in Figure 1) or landfilled (shredded tire). Such stockpiles pose serious environmental and health threats which could have severe long-term effects if not properly addressed. Improperly stored tires are potential breeding grounds for disease-carrying insects and rodents. Discarded tire landfilling is responsible for a serious ecological threat. Mainly discarded tires disposal areas contribute to the reduction of biodiversity as the tires hold toxic and soluble components. Secondly although discarded tires are difficult to ignite, this risk is always present. Once tires start to burn down due to accidental causes, high temperature takes place and toxic fumes are generated (Day *et al.*, 1993) besides the high temperature causes tires to melt, thus producing an oil that will contaminate soil and water (Chen *et al.*, 2007) in addition to air pollution problem. In order to properly dispose of huge amount of discarded tires, the use of innovative techniques to recycle them is important. Worldwide, discarded tires have been recycled for different purposes such as energy recovery (use of tire derived fuel in cement kilns, paper mills or power plants); tire pyrolysis for producing gas, oil, and char (Shu and Huang, 2014) civil engineering applications (lightweight fill for embankments and retaining walls, leachate drainage material and alternative daily cover at municipal solid waste landfills, insulating layer beneath roads and behind retaining walls, modifiers to asphalt paving mixtures, an additive to Portland cement concrete, light weight fillers, etc.) (Al-Akhras and Samadi, 2004; Benazzouk *et al.*, 2004; Merino *et al.*, 2007; Chen *et al.*, 2013).

Figure-1. Stockpile of discarded tires

On the other hand, the consumption of natural aggregates (river sand, stone, etc.) for concrete production is rapidly increasing in countries around the world in order to meet the increasing needs of infrastructural development in the recent years. Due to the overexploitation in many countries, the availability of these natural aggregates has been decreasing (Rashad, 2013; Rashad, 2014). The increasing shortage of natural aggregates has created an opportunity for using by-products as fine aggregate. Reuse of waste rubber derived from discarded tires as a partial or full replacement of natural aggregates in construction activities not only reduces the demand for exploitation of natural raw materials, but also reduces environmental pollution problems associated with the disposal of discarded tires (Rashad, 2016). In this regard, a number of studies on the use of rubber aggregate derived from discarded tire for replacing natural aggregates in concrete have been conducted recently. Rubber aggregates are obtained from discarded tires using two different technologies: mechanical grinding at ambient temperature and/or cryogenic grinding at a temperature below the glass transition temperature (Eleazer *et al.*, 1992; Nagdi, 1993). Although previous studies have achieved encouraging results, there are still several aspects related to the effects of replacing volume for traditional aggregates by rubber aggregate and the effects of size and shape of rubber particles on the mechanical properties of concrete, that need to be further studied. This paper presents the results of the first ever study in Vietnam which aims to explore the possibility to use rubber particles derived from discarded tire as aggregates for replacing fine and coarse natural aggregates to produce cement concrete. The study results are expected to promote the recycling activities for rubber from discarded tires towards resource recovery and environmental protection in Vietnam.

2. MATERIALS AND METHODS

2.1. Materials

In this study, the ordinary Portland cement PC 40 and fly ash (FA) were used as the binders. The Portland cement PC 40 is produced by the local company named JSC Vicem But Son Cement with its properties determined according to Vietnam Standard (1995;2003;2011). The Portland cement PC 40 has a specific gravity of 3.1 g/cm^3, the initial setting time of 105 min, and the final setting time 180 min. The percentage of cement retained on a 90 µm sieve as specified by Vietnam Standard (2003) was 0 %. The FA was obtained from the local power plant (Pha Lai Power Plant in Hai Duong province, Northeast of Vietnam). According to ASTM (2015) the FA can be classified as a class F fly ash due to its chemical composition. In addition to having pozzolanic properties, this type of FA also has some cementitious properties. The total content of SiO_2, Al_2O_3, and Fe_2O_3 in FA is 90.51%, which is larger than the value given by ASTM (2015) for class F fly ash. The amount of FA retained on a 45 µm sieve was 23.20%, which is less than the value given in ASTM C618-15 standard (ASTM, 2015). The sand and crushed stone were used as fine and coarse aggregates in the concrete mix, respectively. The major properties of these materials were determined following Vietnam Standard (2006). The sand used complies to the description of ASTM C778 (ASTM, 2013) and its gradation was in agreement to the requirement of ASTM C33/C33M (ASTM, 2016). The sand has a specific gravity of 2.60 g/cm^3 and the fineness modulus of 2.65 mm. Meanwhile, the crushed stone has a specific gravity of 2.65 g/cm^3 and the fineness modulus of 6.48 mm. The size of crushed stone was in the range of 5-20 mm. The coarse (5-20 mm) and fine (2.5-5 mm) rubber particles (Figure 2) used in the experiment were obtained from mechanical shredding of discarded tires. The specific gravity of rubber particles is 1.17 g/cm^3.

(a). Coarse rubber particles (b). Fine rubber particles

Figure-2. Rubber particles used in experimental study.

Eleven mix designs (M0-M10) were studied in the experiment. The control design (M0), containing no rubber, was determined using the absolute volume method, and consisted of 332 kg of cement, 58.5 kg of FA, 680 kg of sand (fine aggregate), 1200 kg of crushed stone (coarse aggregate), 155 kg of water, 2.73 kg of superplasticizer, and all per cubic meter of mix. The other five mixes (M1-M5) had fine aggregate replaced by fine rubber particle of equal volume, in 10% increments, up to 50% rubber replacement. Similarly, the remaining five mixes (M6-M10) had coarse aggregate replaced by coarse rubber particle of equal volume, in 10% increments, up to 50% rubber replacement. The amount of cement, FA, water, and superplasticizer were all held constant, to reduce the number of variables and maintain a water-to-cement ratio of 0.47 for all mixes. The weights of aggregates and rubber in each mix can be found in Table 1.

Table-1. Mixture proportions of concrete (calculated for 1m³ concrete).

Mix ID	Cement	Fly ash	Sand	Crushed stone	Water	Fine rubber particle		Coarse rubber particle		Superplasticizer
	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)	% by volume	Weight (kg)	% by volume	Weight (kg)
M0	332	58.5	680	1200	155	0	0%	0	0%	2.73
M1	332	58.5	612	1200	155	30.18	10%	0	0%	2.73
M2	332	58.5	544	1200	155	60.35	20%	0	0%	2.73
M3	332	58.5	476	1200	155	90.53	30%	0	0%	2.73
M4	332	58.5	408	1200	155	120.71	40%	0	0%	2.73
M5	332	58.5	340	1200	155	150.88	50%	0	0%	2.73
M6	332	58.5	680	1080	155	0	0%	52.27	10%	2.73
M7	332	58.5	680	960	155	0	0%	104.53	20%	2.73
M8	332	58.5	680	840	155	0	0%	156.80	30%	2.73
M9	332	58.5	680	720	155	0	0%	209.07	40%	2.73
M10	332	58.5	680	600	155	0	0%	261.33	50%	2.73

2.2. Test Methods

In order to evaluate the effect of rubber particles derived from discarded tires replacing natural aggregates on the workability of fresh rubberized concrete, slump tests (Figure 3) were performed for all mixes (Table 1) according to Vietnam Standard (1993a).

Figure-3. Slump test set up.

The compressive strength tests were performed for all mixes according to Vietnam Standard (1993b) in order to evaluate the effect of fine and coarse aggregate replacement with fine and coarse rubber particles, respectively on the compressive strength of hardened concrete. Mix proportions used to prepare specimens for the compressive strength tests were those presented in Table 1. One set of three cubic specimens with a side of 150 mm was realized for each mixture studied. The specimens were cast using appropriate moulds placed on a vibration table for 60 seconds in order to obtain a more homogeneous distribution of rubber particles in the concrete mix. After casting, the moulds were left to cure for 24 hours. Once hardened, the specimens were accurately demoulded, placed in a curing room at a relative humidity of 75% and a temperature of 27 ± 2 °C until testing time. The compressive tests were then carried out for both 7 and 28 day aged specimens by an oil-pressure machine under loading control with a capacity of 3,000 kN and the loading rate of 0.4 MPa/s (Figure 4).

Figure-4. Compressive strength test set up.

The flexural strength tests were also performed for all mixes according to Vietnam Standard (1993c) in order to evaluate the effect of fine and coarse aggregate replacement with fine and coarse rubber particles, respectively on the flexural strength of hardened concrete. Employed mix proportions for preparing specimens for the flexural strength tests were the same presented in Table 1. One set of three specimens with measuring 150 × 150 × 600 mm was cast for each mix design. The casting and curing procedures were similar to those reported in the Section 2.3.1 above. For the flexural strength test (Figure 5), three specimens from each mix design were tested by one-point loading configuration with a span of 10 cm using testing machine with a capacity of 10 kN and the loading rate of 0.06 MPa/s. All tests were carried out 28 days after the casting.

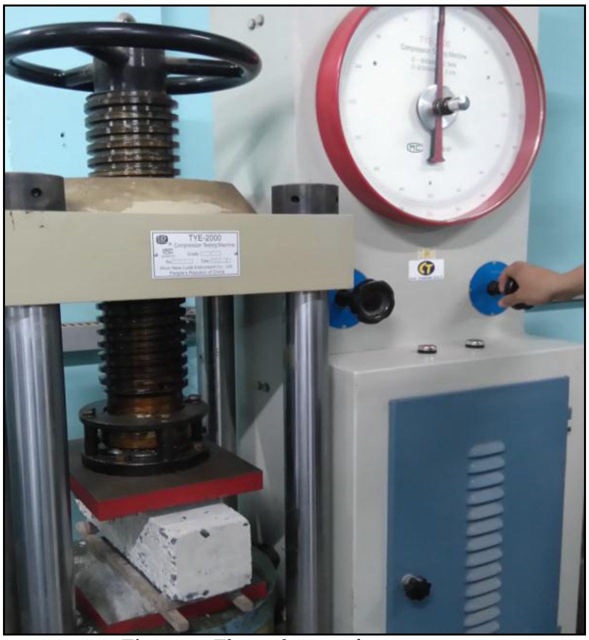

Figure-5. Flexural strength test set up.

The tests for modulus of elasticity of hardened concrete were carried out for the selected mixes (M0, M3, and M8) according to ASTM (2014). Employed mix proportions (M0, M3, and M8) for preparing specimens for the modulus of elasticity tests were the same presented in Table 1. One set of six cylinder specimens with measuring 150 × 300 mm was cast for each mix design. The tests for modulus of elasticity were performed using testing machine with a capacity of 150 T and the loading rate of 241 ± 34 kPa/s (Figure 6). All tests were carried out 28 days after the casting.

Figure-6. Modulus of elasticity test set up.

3. RESULT AND DISCUSSIONS

3.1. Workability of Fresh Rubberized Concrete

The results of slump tests are shown in Figure 7. When sand (fine aggregate) was replaced by fine rubber particle at the low proportions (10% and 20% by volume), it can be seen that the slumps or workability of fresh rubberized concrete were not changed much compared to that of the control mix (M0). At the higher replacing proportions (30%, 40% and 50% by volume), the slumps relatively increased. Our results are in good agreement with the slump test results reported by previous studies (Balaha *et al.*, 2007; Azmi *et al.*, 2008; Aiello and Leuzzi, 2010; Pelisser *et al.*, 2012; Onuaguluchi and Panesar, 2014; Elchalakani, 2015) where the workability of fresh rubberized concrete increased with increasing rubber contents. For instances, Aiello and Leuzzi (2010) showed that the workability of rubberized concrete was slightly improved when coarse or fine aggregates were partially replaced with rubber shreds. They reported that the control concrete exhibited a fluid behavior, while the rubberized concrete showed a hyper-fluid behavior. Similarly, Balaha *et al.* (2007) used ground waste tyre rubber for partial replacement of natural sand at the proportions of 0%, 5%, 10%, 15% and 20%, by volume and they reported that the workability increased as rubber sand content increased. However, it is worth to note that a number of studies reported contrary results with the decreased workability with the inclusion of rubber aggregates in the concrete mixture (Güneyisi, 2010; Ozbay *et al.*, 2011; Raj *et al.*, 2011; Karahan *et al.*, 2012; Rahman *et al.*, 2012; Dong *et al.*, 2013; Ganesan *et al.*, 2013; Grdić *et al.*, 2014; Holmes *et al.*, 2014; Mohammadi *et al.*, 2014).

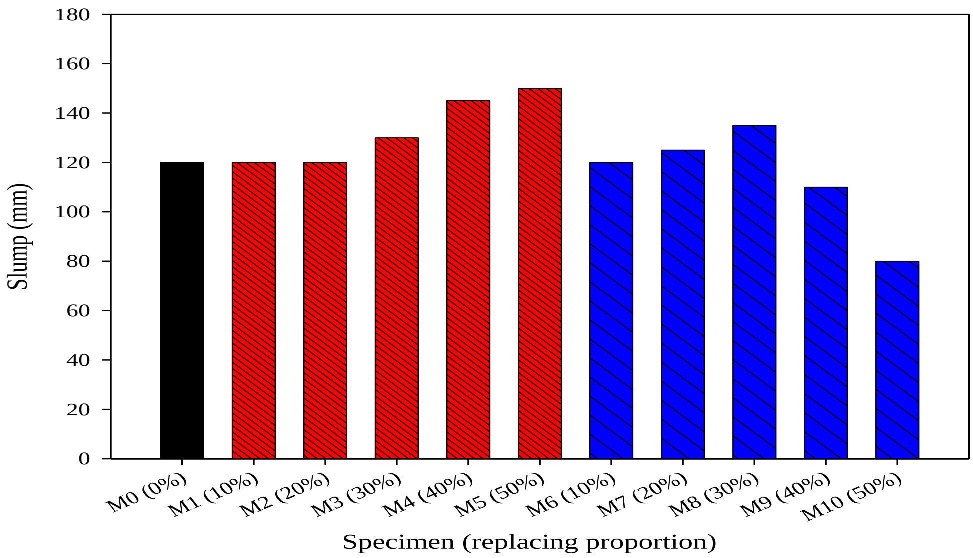

Figure-7. Slump of fresh rubberized concrete compared to plain concrete.

When crushed stone (coarse aggregate) was partially replaced by coarse rubber particle at the low and medium proportions (10%, 20%, and 30% by volume), it was observed that the slumps slightly increased in comparing to that of the control mix. However, when the replacing proportion increased to 40%, the slump slightly decreased. Especially, at the replacing proportion of 50%, the slump was found to be decreased significantly. This can be explained that when coarse rubber particles were used at high proportion, the contacts among coarse rubber particles and among rubber particles with other aggregates were increased leading to the increase in the inter-particle friction between rubber particles and other aggregates, thus reduce the workability of fresh rubberized concrete. Our slump test results for the case of coarse rubber particle replacing coarse aggregate are also similar to those reported by the other studies (Khaloo *et al.*, 2008; Turgut and Yesilata, 2008; Pacheco-Torgal *et al.*, 2012; Wang *et al.*, 2013; Guo *et al.*, 2014; Youssf *et al.*, 2014) partially replaced sand in concrete block mixtures with rubber aggregate at the proportions ranging from 10% to 70% with an increment of 10%, by volume. Their results showed that the workability increased with the inclusion of rubber aggregate up to 40%, whereas the inclusion of 50-70% rubber aggregate caused the decrease of workability. Pacheco-Torgal *et al.* (2012) reported that when rubber chips used to partially replace for coarse aggregate, the slump increased with increasing volume of rubber aggregates up to the replacing proportion of 15%, and the slump decreased as the replacing proportions were larger than 15% by volume. Compared results on the workability of the fresh rubberized concrete between this study and other studies suggest that the workability may be largely dependent on the specific characteristics of the rubber aggregates used in the concrete mixture. Therefore, future studies should focus more on the characteristics of rubber aggregates (size, shape, pretreatment of rubber aggregates, etc.) that influence the workability of the rubberized concrete.

3.2. Mechanical Properties of Hardened Rubberized Concrete

3.2.1. Compressive Strength

The 7-day and 28-day compressive strengths as a function of different replacing proportions of rubber particles with different sizes are presented in Figure 8. As expected, the compressive strength increased with curing time for the control specimen (M0) and other specimens (M1-M10) at all replacing proportions. The compressive strength of the control specimen was evaluated as 34.5 and 49.5 MPa at 7 and 28 days, respectively. The test results indicated that there was a significant reduction in the compressive strength of the rubberized concrete as the rubber content increased in comparison to that of the control specimen at both 7 and 28 days. It is found that depending on the proportion and size of replacing rubber particles, the degree of reduction in the compressive strength was different (Figure 9). At the replacing proportion of 10%, the reduction in the compressive strength of the specimens containing fine rubber particles at 7 and 28 days were 8.7 and 9.7%, respectively; whilst the counterpart for the specimens containing coarse rubber particles at 7 and 28 days were 16.2 and 30.3%, respectively. This suggests that using coarse rubber particles lowered the compressive strength of the rubberized concrete more than the case of using fine rubber particles. When the replacing proportions increased to 20, 30, and 40% by volume, the compressive strengths also decreased accordingly, however, the degrees of reduction between two cases (the specimens containing fine and coarse rubber particles) at the same replacing proportions gradually became smaller than that at the replacing proportion of 10%, especially for the specimens at the curing time of 28 days. The replacing proportion of 50% caused the largest reductions in the compressive strength of specimens containing fine and coarse rubber particles at both 7 and 28 days. The test results imply that using fine rubber particles, instead of fine natural aggregate, at the low replacing proportion (up to 10%) might not cause the significant effect on the compressive strength of the rubberized concrete. Overall, our results agreed well with the previous studies which reported that the inclusion of increasing rubber contents caused progressive losses in the compressive strength of the rubberized concrete and the replacement of coarse aggregate in the concrete mixture lowered the compressive strength more than that of fine aggregate (Ganjian *et al.*, 2009; Yilmaz and Degirmenci, 2009; Aiello and Leuzzi, 2010; Pelisser *et al.*, 2011; Gesoğlu *et al.*, 2014; Holmes *et al.*, 2014; Youssf *et al.*, 2014).

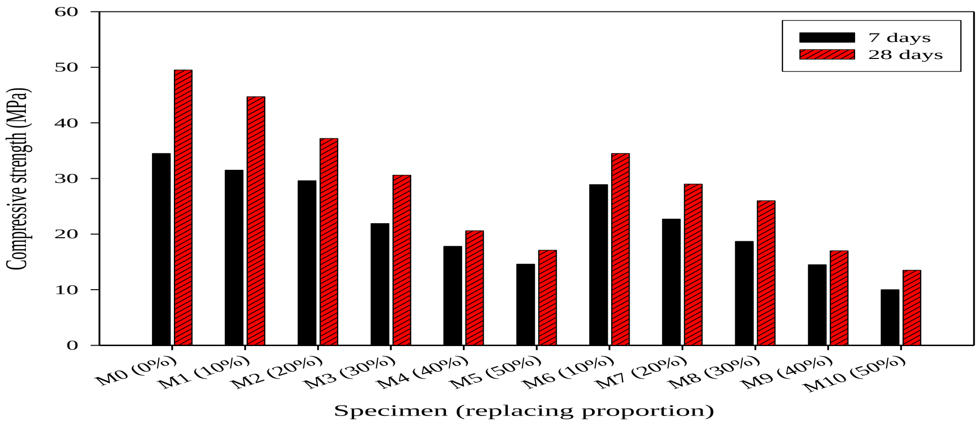

Figure-8. Compressive strength of hardened rubberized concrete compared to plain concrete.

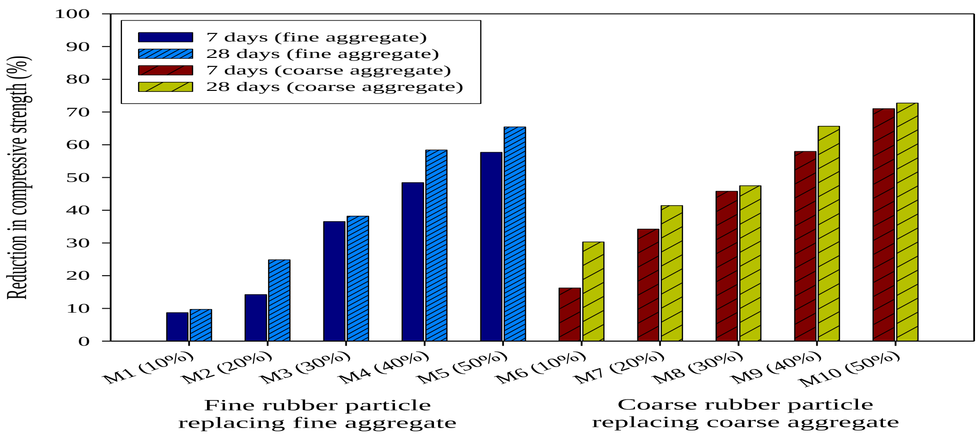

Figure-9. Reduction (%) in compressive strength of rubberized concrete compared to plain concrete.

There are several possible reasons for the reduction in the compressive strength of the rubberized concrete which largely influenced by the physical and mechanical properties of the constituent aggregates. First, it could be attributed to the physical properties of the rubber particles which are less stiff than the cement paste. This could lead to the deformability of the rubber particles compared with the surrounding cement paste that resulted in the rapid development of cracks around the rubber particles in a fashion similar to that occurring with air voids in normal concrete (Taha *et al.*, 2008; Ganjian *et al.*, 2009; Thomas and Gupta, 2016). The second reason for the decrease in the compressive strength is the poor bond between the rubber particles and the cement paste in comparing to the bond between the natural aggregates and the cement paste. Corinaldesi *et al.* (2011) and Raj *et al.* (2011) indicated that the low strength of the rubberized concrete is due to the weak interface or the transition zone between the rubber particles and the cement paste. Such a weak interface could initially cause the micro-cracks which eventually grow to macro-cracks, and result in the failure of the rubberized concrete specimen under compression. Our test results showed the surfaces of the failed specimens having quite clean rubber particles with little cement paste attached which implies the poor bond between the rubber particles and the cement paste. The third reason for the reduction in the compressive strength of the rubberized concrete might be associated with the low specific gravity of rubber coupled with the poor bond of the rubber particles with other aggregates, which might make the rubber particles moving upwards during vibration in the casting process and concentrating at the top layer of the specimen. This could result in a non-homogeneous distribution of rubber particles and other aggregates, and therefore reduce the strength of the specimen. The other reason for the decreased compressive strength could be the increased matrix porosity or weakness points in rubberized concrete matrix which largely depending on the size, density, and hardness of the aggregates as explained by the previous studies (Lee *et al.*, 1998; Chung and Hong, 1999; Khatib and Bayomy, 1999; Albano *et al.*, 2005; Taha *et al.*, 2008; Turki *et al.*, 2009; Ozbay *et al.*, 2011; Karahan *et al.*, 2012).

3.2.2. Flexural Strength

The influences of different replacing proportions and different sizes of the rubber particles on the 28-day flexural strengths of the rubberized concrete are presented in Figure 10. The flexural strength at 28 days of the control specimen was 7.2 MPa. Similar to the case of the compressive strength, the test results indicated that there were significant reductions in the flexural strength of the rubberized concrete specimens compared to the control specimen when the replacing proportions increased. The degree of reduction in the flexural strength was also largely influenced by the size of replacing rubber particles as shown in Figure 11. As expected, a smaller reduction of the flexural strength was observed when the fine aggregate was replaced by the fine rubber particle, compared to the case of coarse rubber particle, for all replacing proportions. This could be attributed to the filling effect of fine rubber particles that increase the compactness of the rubberized concrete specimens, reduce the stress singularity at internal voids, and thus reduce the likelihood of fracture (Su *et al.*, 2014). The test results suggest that using fine rubber particles for replacing fine natural aggregate at the low replacing proportion (up to 10%) might not cause the significant effect on the flexural strength of the rubberized concrete which similar to the case of the compressive strength.

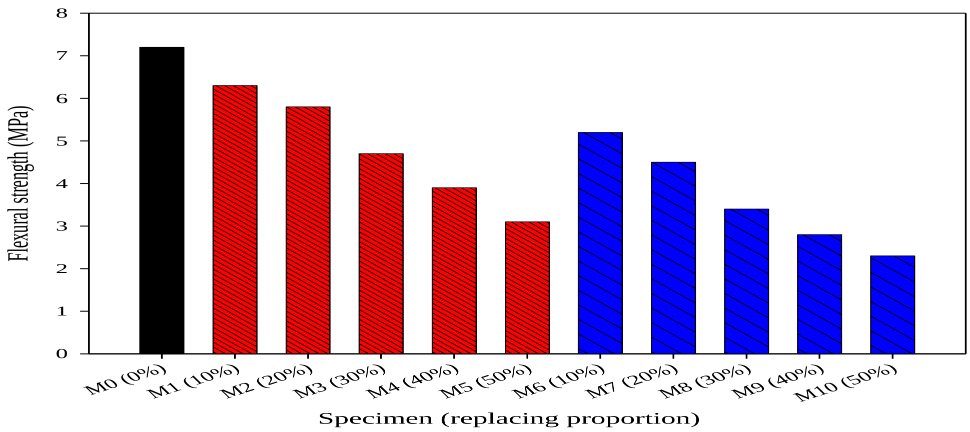

Figure-10. Flexural strength at 28 days of hardened rubberized concrete compared to plain concrete.

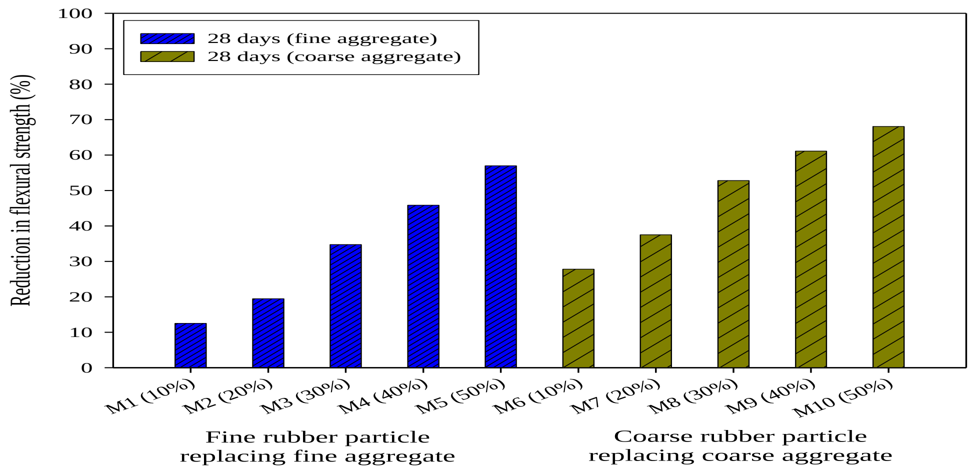

Figure-11. Reduction (%) in flexural strength at 28 days of rubberized concrete compared to plain concrete.

Similar test results were reported by the previous studies (Ganjian *et al*., 2009; Aiello and Leuzzi, 2010; Su *et al*., 2014). For instances, Aiello and Leuzzi (2010) reported that the rubberized concrete with the inclusion of 50% and 75% by volume of coarse aggregate replacement presented 28% decrease in the flexural strength compared to the plain concrete. Whereas, the rubberized concrete obtained with 50% and 75% by volume of fine aggregate replacement showed a decrease in the flexural strength of about 5.8% and 7.3%, respectively compared to the plain concrete. However, it is worth to note that the other studies have reported quite different results compared to ours with the increased flexural strength of the rubberized concrete when the rubber aggregate used to replace fine aggregate at the low replacing proportions (mainly less than 20% by volume), and the decreased flexural strength at the high replacing proportions. For instances, Yilmaz and Degirmenci (2009) reported that the rubberized concrete specimens using tire rubber (in the form of fibers) up to 20% by volume showed the higher flexural strength than the control specimens, and the flexural strength decreased as the rubber contents increased from 20-30%. Gupta *et al.* (2014) reported that the flexural strength of the rubberized concrete containing rubber ash decreased as the content of rubber ash increased, whereas the flexural strength of modified concrete (containing 10% rubber ash and a varying content of rubber fibers) increased with the increasing content of rubber fibers. These studies showed that the increased flexural strength of the rubberized concrete associated with the use of tire rubber in the form of fibers. This further suggests that future studies should focus on the characteristics of the rubber aggregates that enhance the flexural strength of the rubberized concrete.

3.2.3. Modulus of Elasticity

The test results for modulus of elasticity of rubberized concrete are shown in Table 2. It was found that the modulus of elasticity of rubberized concrete was smaller than that of control concrete. The modulus of elasticity of the specimen M3 (fine rubber particle replacing 30% fine aggregate) and M8 (coarse rubber particle replacing 30% coarse aggregate) was about 70.3 and 47.4 %, respectively of the counterpart of the control specimen M0. It suggests that using coarse rubber particle for replacing coarse aggregate caused a larger reduction in the modulus of elasticity compared to the case of using fine rubber particle for replacing fine aggregate. Similar results were also reported by Gesoğlu *et al.* (2014).

Table-2. Modulus of elasticity of rubberized concrete.

Mix ID	Replacing proportion for fine aggregate (%)	Replacing proportion for coarse aggregate (%)	Modulus of elasticity (GPa)	Compared to control specimen (%)
M0	-	-	42.8	100
M3	30	-	30.1	70.3
M8	-	30	20.3	47.4

4. CONCLUSIONS

This study has conducted the experiment to investigate the properties of the fresh and hardened rubberized concrete made by replacing the natural aggregates with the rubber particles derived from discarded tires having the similar sizes of the replaced natural aggregates. The major findings of this study can be summarized as the following:

- The workability of the fresh rubberized concrete was improved when replacing the natural fine aggregate with the fine rubber particles at the replacing proportions of 30-50% by volume, and when replacing the natural coarse aggregate with the coarse rubber particles at the replacing proportions of 10-30% by volume;

- With respect to the mechanical properties of the hardened rubberized concrete, a larger reduction in the compressive and flexural strengths was generally observed when the replacing proportions increased, and especially when the coarse aggregate rather than the fine aggregate was replaced by the rubber particles at all replacing proportions (10-50% by volume). The modulus of elasticity of rubberized concrete was found to be smaller than that of control concrete.
- Using the fine rubber particles for replacing the fine natural aggregate at the low replacing proportion (up to 10%) might not cause the significant effect on the compressive and flexural strength of rubberized concrete.

Based on the findings of this study, it is suggested that rubberized concrete using the fine rubber particles for replacing the fine natural aggregate at low proportion could be used for civil engineering applications as plain concrete. However, further studies are recommended to verify the workability and the mechanical properties of rubberized concrete mixtures prepared by partially replacing both the natural coarse and fine aggregates, and to evaluate the effect of the specific characteristics (e.g. size, shape, pretreatment) of the rubber aggregates on the workability and the mechanical properties of the rubberized concrete, especially the characteristics that could increase the mechanical properties of the rubberized concrete. In addition, the other properties of rubberized concrete such as thermal conductivity, thermal resistivity, heat transfer, conductance value, sound absorption, etc. should be investigated in order to propose the appropriate application of rubberized concrete in the real life. Overall, the study results are expected to promote the recycling activities for rubber from discarded tires towards resource recovery and environmental protection in Vietnam.

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