Key Engineering Materials
ISSN: 1662-9795, Vol. 879, pp 49-61

Submitted: 2020-08-19
Revised: 2020-09-09
Accepted: 2020-11-04
Online: 2021-03-15

Properties of Mortar with Waste Tyre Rubber as Partial Sand Replacement

Chong Beng Wei[1,a], Rokiah Othman[1,b], Tan Wei Sheng[1,c], Ramadhansyah Putra Jaya[2,3,d*], Mohd Mustafa Al Bakri Abdullah[3,e]

[1]Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang, Malaysia

[2]Department of Civil Engineering, College of Engineering, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang, Malaysia

[3]Center of Excellence Geopolymer and Green Technology. Universiti Malaysia Perlis, 01000 Kangar, Perlis, Malaysia

[a]bengweichong95@gmail.com, [b]rokiah@ump.edu.my, [c]twei260@gmail.com, [c]ramadhansyah@ump.edu.my, [d]mustafa_albakri@unimap.edu.my

Keywords: mortar; tyre rubber; compression; flexural; water absorption; acid attack.

Abstract. Around 1000 million waste tyres are generated annually and over 5000 million more are estimated to be discarded by 2030. It is estimated that one waste tyre is discarded per person in developed areas; hence 1 billion waste tyres are disposed worldwide. Waste tyre is difficult to manage as it takes up space, is difficult to compress and combustion of tyre releases highly toxic substance into the air. Hence, most of them end up in the landfill, as past research data estimated that currently 4 billion waste tyres can be found in landfills. In this study, up to 30% tyre rubber with a fine grind size of 300nm to 500nm was used as partial sand replacement in type N cement mortar. The rubber was treated with 1M NaOH solution to enhance its ability to bond with the other constituent materials. Tests were conducted to determine the properties of rubberised mortar, including consistency, compressive strength, flexural strength, water absorption and acid attack. From the test result, tyre rubber reduced the consistency and strength of mortar. Mathematical regression model showed that reduction of strength occurred in a second-order polynomial function with percentage of rubber. It was concluded that at up to 20% replacement rubberised mortar has the best resistance against water absorption and acid attack while still achieving the target strength.

Introduction

Due to urbanization and economic development, waste generation in Malaysia is increasing from time to time. Malaysians produce an average of 30,000 tons of waste daily and only 5 percent is recycled [1]. The amount of waste generated is expected to increase by 3% annually as a result of urban migration, affluence and rapid development [2]. However, the low recycling rate means that most of the waste in Malaysia end up being sent to the landfill [3]. This is not a long term solution, and the over-reliance on landfills had led to various problem such as insufficient capacity, environmental degradation, odour, and the contamination of soil and water [4]. A proper waste management system, such as exploring the potential of certain waste to be reused and recycled should be practiced for the betterment of the future.

Disposal of waste tyres is a challenging issue across the world and more prominent in developing countries. Around 1000 million waste tyres are generated annually and over 5000 million more are estimated to be discarded by 2030 [5]. The problem of waste tyre is not limited to Malaysia but happens worldwide. It is estimated that one waste tyre is discarded per person in developed areas, hence 1 billion waste tyres are disposed worldwide [6]. In Taiwan, over 1,00,000 tons of waste tyres are generated annually, while the United States has the world's highest waste tyres generation at 270 million annually, followed by Japan with over 110 million waste tyres for each year [7]. In India, millions of tons of waste tyres are produced every year and around 60 percent of said waste are disposed from urban and rural areas [8]. Roughly 30,000,000 million waste tyres are produced in

France per year [9]. In Australia, the accumulation rate of waste tyres is rising at 2%, and it is estimated more than 20 million waste tyres were disposed in landfills by 2010 [10]. Disposal of waste tyre is difficult for a number of reasons. Combustion of tyre is a fire hazard and the process releases highly harmful substance into the air and the residue from combustion is a pollutant that can damage the quality of soil and water [11][12]. Landfill can deal with waste with high organic content without the need of high technology, so it is widely practiced by developing countries with technological and financial constraints [13][14]. However, even when the tyre waste was sent to landfill, it takes up a lot of space and deplete capacity rapidly. Vulcanized rubber also has low degradation, so waste tyres may break through landfill covers, outflow and cause pollution [15]. Hence, sending waste tyres to the landfill is not a proper solution as it causes environmental problems [16]. However, despite those complications, landfilling is still adapted as a popular disposal system in Malaysia.

The reusing and recycling rate of waste tyres is globally low. While some initiatives have been taken to recycle waste tyre or use them as fuel, more than 70% waste tyres generated worldwide end up in stockpile and landfill [17]. A possible solution to this problem is by incorporating waste tyre rubber into cement products, especially with the importance of sustainable development in construction gaining traction in the recent years. The introduction of rubber material in concrete can circumvents one of the greatest weakness of cement products, which is its brittle nature [18]. Proper addition of rubber improves ductility, energy absorption and reduces concrete density, all of which is beneficial to the material. In short, it improves the durability of concrete to resist aggressive environment [19]. Rubberised concrete has been examined to be suitable for pavement and structure construction applications [20]. Lightweight concrete can also be produced with the proper usage of rubber material [21]. However, the addition of tyre rubber crumb into concrete impacts its mechanical properties. Sofi [5] concluded that the addition of rubber resulted in lower compressive strength and flexural strength. The weakening effect was proven for experiments involving normal concrete [22], masonry units [23], and high performing concrete [24]. However, in all cases, the performance of product fulfills the target as long as the amount of replacement was controlled below certain point. In addition, proper handling and treatment of rubber crumb minimises the weakness incur by the addiction of rubber [25]. Pre-treatment can be conducted with any solvent or synthetic resin for similar effect. It has been strongly agreed that pre-treatment of rubber crumb is necessary even though the best method and solution for treatment is yet to be concluded [26]. Regardless, rubber treated with 1 molar solution of NaOH solution shows greatly improved properties compared to raw rubber [27]. The purpose of treatment is to improve the bonding of rubber with cement paste as a weak bond between material is the cause of reduced strength. Ponding rubber in NaOH solution for 30 minutes in room temperature enhances the ability of rubber to form stronger bond with cement [25].

The objective of the study is to investigate the properties of mortar with fine-grinded tyre rubber as sand replacement. While it has been known that replacement of sand with tyre rubber decreases the mechanical performance of cementious product, the commonly used grind sizes are between 1mm and 4mm [27-29]. In this study, fine-grinded tyre rubber of size 300nm to 500nm which approaches the nano-scale is used. The reduction of strength due to the effect of tyre rubber is studied mathematically at 1 day, 7 days and 28 days mortar age. Type-N mortar is prepared with sand being replaced by 0%, 10%, 20% and 30% fine-grinded tyre rubber. Various tests were conducted to study the consistency, strength, water absorption and acid attack of the specimens. The effect of tyre rubber on the parameters were analysed in detail with correlations and reference to design standards. The study provides insight on the extend of tyre rubber replacement possible for the best durability while retaining the desirable strength of type-N mortar for cheaper and greener construction.

Material and Properties

Tyre waste was manufactured and imported from China and used as additive to the mortar while the other materials used are locally available. 'Orang Kuat' Ordinary Portland Cement from local manufacturer was used. The cement grade is 52.5N and it fulfils the specification of MS EN 197-1: 2014. Table 1 shows the chemical composition and the physical properties of the cement powder.

Table 1
Chemical composition and physical properties of OPC

Tests		Units	Specification	Test
			Chemical Composition	
Sulfate Content (SO_3)		%	Not more than 3.5	2.1
Chloride (Cl^-)		%	Not more than 0.10	0.01
			Physical Properties	
Fineness (According to Blaine)		m^2/kg	-	440
Setting time : Initial		mins	Not less than 75	155
Soundness		mm	Not more than 10	0.8
Compressive Strength				
(Mortar Prism)	: 7 days	MPa	Not less than 16	24.0
	: 28days	MPa	$32.5 \leq x \leq 52.5$	35.2

River sand was used as the fine aggregate to produce mortar. Sieve analysis in accordance with BS812: 103 was carried out to identify the grading of the aggregate. Only aggregate that retained below sieve 4.75mm was used. The sieve shaker machine consists of several size which range from 4.75mm to 0.075mm. For this research, the sieves were arranged in descending order which from the size of 4.75mm at the top, followed by 3.35mm, 2.0mm, 1.18mm, 0.6mm, 0.425mm, 0.30mm, 0.212mm, 0.15mm and finally the pan at bottom. The 500g of sand will be placed at the top of sieve and covered it with cover plate properly and ran the machine for 10 to 15 minutes. During the shaking process, the aggregate will be passing through the sieve. If the aggregate size is bigger than the sieve it will retained. Table 2 shows the result of the analysis and the equipment used for the process.

Table 2
Grading of fine aggregate

BS Sieve Size (mm)	Weight of Sieve (g)	Weight of Sieve + Sample (g)	Weight of Sample(g)	Cumulative %	Passing %
4.750	404.12	408.33	4.21	0.84	99.16
3.350	539.83	548.92	9.09	2.67	97.33
2.000	550.21	583.53	33.32	9.34	90.66
1.180	485.43	553.31	67.88	22.94	77.06
0.600	483.68	625.90	142.22	51.44	48.56
0.425	453.94	521.37	67.43	64.95	35.05
0.300	448.33	513.24	64.91	77.96	22.04
0.212	429.24	473.25	44.01	86.78	13.22
0.150	426.27	463.16	36.89	94.17	5.83
0.000	243.23	272.33	29.10	100.00	0.00

Tyre rubber crumb was in powder form passing the 180µm sieve (mesh 80). Figure 1 showed the size distribution of the tyre rubber. The particle size of the rubber fell between 300nm to 500nm. Pre-treatment was done with saturated sodium hydroxide aqueous solution. The solution was prepared by diluting one mole of solid NaOH, which is 40 grams of the compound, into 1 liter of distilled water. The tyre waste was soaked in the solution for 20 minutes at room temperature, washed with water, and then dried at ambient temperature for 24 hours before being used.

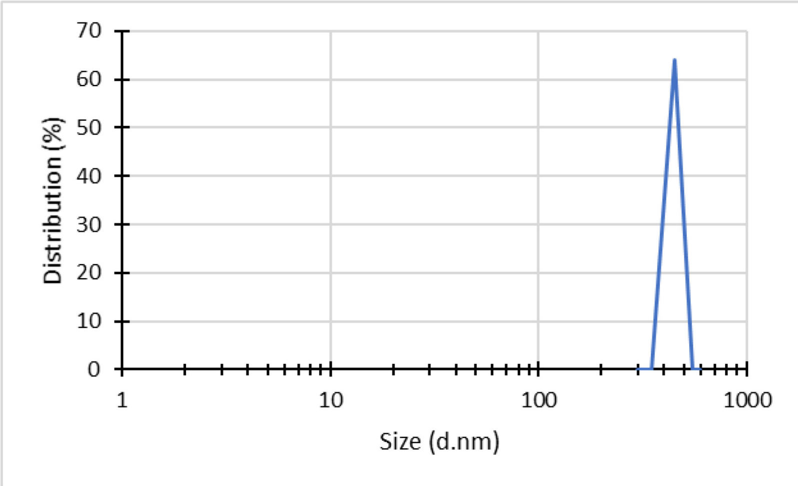

Fig. 1 Tyre rubber size distribution intensity

Experimental Work

Mixing proportion, casting and curing. Type N mortar was prepared for the study. The design and preparation of the mix was according to the standard of ASTM C1329-05. Type N mortar is of general purpose uses and is the most common type of mortar being used unless special characteristics are required. The strength is categorized as medium with a minimum of 750psi or 5.2MPa. The targeted 28 days strength was between 1500psi and 2400psi, or about 10MPa to 16MPa. The usage of type N mortar is wide, including exterior and interior load bearing installation, soft stone masonry and load bearing walls. The proportion of cement: sand: water used was 1: 2.75: 0.6. Tyre rubber crumb was used to replace sand at 10%, 20%, and 30% by weight. The control specimens were labelled as 0TR, while rubberised specimens were labelled 10TR, 20TR and 30TR based on the percentage of rubber used as replacement. For producing the mortar cubes with size 50mm x 50mm x 50mm, the volume of mortar needed was small. So, the process was carried out by hand. Trial mixes were done to observe the amount of additional water volume needed according to the material water absorption test. To obtain a uniform mortar mix, the fine aggregates were first poured into the mixing plate, and then followed by the tyre waste. The materials were mixed uniformly. Cement powder was added later to reduce the water absorption for the mixture. Water was added slowly and the materials were mixed manually for a few minutes. Filling was done in three layers into the mould to ensure uniformity and minimize air void. All mortar specimens were fully immersed in water curing pond until the day of testing. The temperature of the surrounding was 24 ± 3ºC.

Flow table test. Flow table test was conducted in accordance to ASTM C1437-15 to determine the consistency of the fresh mortar. The consistency check can determine the flow ability of the mortar with the tyre waste as sand replacement. The flow table was cleaned and placed on the flat surface. After that the mould was placed at the center of the tabletop. Fresh mortar was added into the mould by three layers. For each layer, 20 times of tamping was done by using a tamping rod to ensure the uniform filling of the mould. Next, the upper mould was leveled to remove the excess fresh mortar. After that, the table was dropped immediately with a drop height of 12.5mm. This process was repeated for 25 drops in 15 seconds.

Compressive strength. The compressive strength test was carried out according to the British Standard (BS 1881 : Part 116). Before carrying out the test, the surface of the compressive strength machine was wiped clean to be free from grits or any substances. The size of the mortar cube being prepared was 50mm x 50mm x 50mm. The specimens were put under loadings and the maximum loads were recorded. Other than that, the type of failure and the surface appearance of the cubes were observed as well. The testing of the cubes was taken at age of 1, 7, and 28 days. There were three specimens for each age of the cubes to obtain the average data for more accurate results. The loading rate of the compression test machine was 1.00 kN/s and start load of 5.00 kN and stop load of 10%.

Flexural strength. Flexural strength was tested using centre point loading method in accordance to the British Standard (BN EN 12390-5:2009). The mortar beam specimens for conventional and rubberised mortar were used to determine the tensile strength of the mortar. Non-reinforced of beam mortar specimens with the dimension of 40mm × 40mm × 160mm was used for this test. The specimens were tested until they failed, and the final force applied on the specimen was recorded.

Water absorption. The characterization of pores structure in mortar was determined using the water absorption testing in accordance with BS 1881: Part 122 (2011). In this research, the mortar cubes of 50 x 50 x 50 mm were selected to examine the rate of water absorption. After 28 days curing, the mortar cubes were dried inside oven for 72 h ± 2h. After the drying process, the specimens were cooled in sealed container for 24 h ± 0.5h. Immediately after the cooling process, the specimens were weighed and the mass was recorded. The specimens were then fully immersed in water at which there was 25 mm ± 5 mm of water above were shaken to remove water from the specimen surface. The specimen was then dried up using cloth as rapidly as possible until all water on the specimen surface was completely removed. The specimens were weighed and the mass was recorded.

Acid attack. Mortar cubes of 50 x 50 x 50 mm were used to test for acid attack in accordance with ASTM C267 – 01 (2012). After 28 days water curing, the initial weight of the mortar specimens were measure. Sulphuric acid solution of pH3 was prepared and the cube specimens were submerged inside the solution. After every 100 hours, the weight of the specimens was measured and any changes in term of specimens' shape and deterioration was observed till the period of 672 hours or 28 days. The pH of the sulfuric acid solution was regularly monitored and adjusted to keep it constant. After the period, the cube specimens were taken out and crushed to observe the amount of strength loss.

4.0 Result and Discussion

Flow table test. Table 3 presents the result of flow table test. The consistency of the control specimen was 110%, which achieves the acceptable range of consistency of a good mix, which is suggested to be around 105 ± 5% [31]. However, a significant drop in consistency was observed for all rubberised mortar specimens. The consistency dropped to 35% for 10TR, and further decreased with more tyre rubber to a mere 10.5% for 30TR. Reduction of workability with replacement of tyre rubber was common and consistent with other research [32]. The reduction may be attributed to two reasons. First, the rough surface and elastic behaviour of rubber particle can increase friction between rubber particles and other ingredients under free flow [33]. Second, fine tyre rubber absorbed a huge amount of water almost equivalent to its weight, which used up the water needed by mortar to achieve the desired consistency [34]. To achieve the target consistency, additional water was carefully introduced into the mix to help it reach the target. After additional water, 10TR and 20TR achieved consistency of 110% and 115.5% respectively. 30TR on the other hand saw a sharp increase in consistency to 142.5%.

Table 3
Flow table test result

Mortar	Flow Value before additional	Flow Value after additional
0TR	110.0	-
10TR	35.0	110.0
20TR	19.0	115.5
30TR	10.5	142.5

Compressive strength. Table 4 shows the compressive strength of mortar specimens at 1 day, 7 days and 28 days. The control specimen (0TR) had the highest compressive strength, which was 7.095 N/mm^2 at 1 day, 22.797 N/mm^2 and 7 days and 27.460 N/mm^2 at 28 days. At 28 days, the compressive strength of 10TR was 16.107 N/mm^2, and this value continued to drop for 20TR and 30TR, which was 8.977 and 6.941 N/mm^2. For 1 day and 7 days specimens, the trend of compressive strength was the same. In general, the compressive strength of mortar deceased with increase of tyre rubber replacement. For type N mortar, the target 28 days compressive strength was 10 to 16 N/mm^2. So, 0TR and 10TR achieved the target while 20TR was slightly less than the target. 30TR saw a significant drop in compressive strength that may made it unsuitable to be used. The reduction in compressive strength was attributed to the weak bonding between tyre rubber and Portland cement [7][21]. The correlation between compressive strength of mortar and percentage of waste tyre rubber was carried out to study the relationship between the two variables. The correlation was tested for both linear and polynomial relation, and the result of the analysis was tabulated on Table 5. For 1-day result, both linear and polynomial expression was able to define the relationship with great accuracy of R^2 equal to 0.973 for linear relation and 0.9902 for polynomial relation. At 7 days and 28 days however, the relationship between the variables became more polynomial, as indicated by the lower accuracy of linear equations compared to polynomial equations. For 7 days, the linear equation had R^2 value of 0.8059, while polynomial equation maintained a good correlation factor of 0.9979. Similarly, polynomial equation expressed 28 days result with greater R^2 value. It can be concluded that replacement of sand with waste tyre rubber negatively impacts the compressive strength linearly at early age, but evolved into polynomial relation at 7 days and beyond.

Table 4
Compressive strength test result

Cube Specimen	Compressive Strength (N/mm^2)		
	1 day	**7 days**	**28 days**
0TR	7.095	22.797	27.460
10TR	4.794	10.754	16.107
20TR	3.672	6.108	8.977
30TR	2.126	6.048	6.941

Table 5
Correlation of compressive strength and percentage of tyre rubber

Mortar Age	Linear Correlation		Second-Order Polynomial Correlation	
	Equation	**R^2**	**Equation**	**R^2**
1 day	$y = -0.16x + 6.83$	0.9793	$y = 0.0019x^2 - 0.22x + 7.01$	0.9902
7 days	$y = -0.55x + 19.66$	0.8059	$y = 0.030x^2 - 1.45x + 22.66$	0.9979
28 days	$y = -0.69x + 25.17$	0.9156	$y = 0.023x^2 - 1.39x + 27.50$	0.9999

Compressive strength activity index. Figure 2 shows the compressive strength activity index of mortar specimens. According to ASTM C311-18, strength activity index is used to determine the strength development of mortar compared to control when fly ash or nature pozzolan is used. While tyre rubber was used to replace sand and not as a pozzolan, the method could still be adopted to analyse the performance of mortar with waste material replacement. For 10TR, the strength index was 68% at 1 day, 47% and 7 days and 59% at 28 days. For 20TR and 30TR, the strength index was between 25% and 33% except for 20TR at day 1 which was 52%. This showed that the drop in strength was significant especially beyond 20% tyre rubber replacement. Tyre rubber not only had a weak bond with cement paste, but also required more water to be added in order to achieve the target consistency of mortar. Addition of water further reduced the strength of mortar [35].

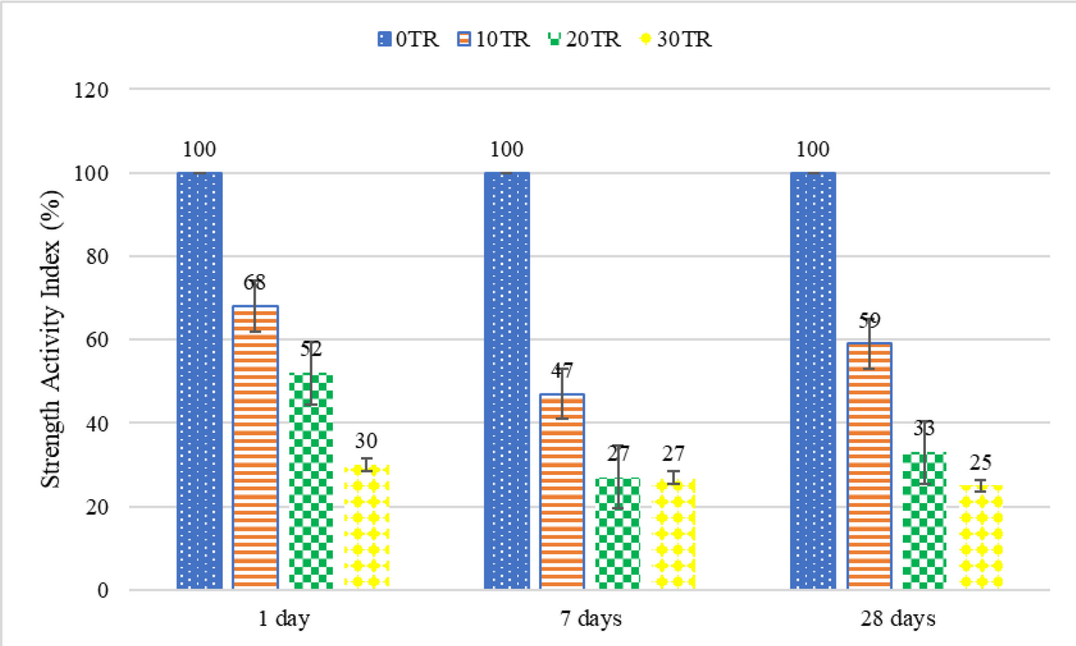

Fig. 2 Compressive strength index of tyre rubber mortar

Flexural strength. The flexural strength of mortar specimens was shown on Table 5. Similar with the result of compressive strength, 0TR had the highest strength. At 28 days, 0TR had flexural strength of 6.499 N/mm^2. This value dropped to 4.025 N/mm^2 for 10TR, and 2.669 N/mm^2 for 20TR and lastly 2.501 N/mm^2 for 30TR. The trend was the same for 1 day and 7 days specimen. At 1 day, the flexural strength of 0TR was 2.403 N/mm^2, dropping to 0.860 N/mm^2 at 30TR. For 7 days, 0TR had a flexural strength of 5.229 N/mm^2 while 30TR had only 1.911 N/mm^2. The addition of water and tyre crumb impacts the flexural strength of mortar in the same way as compressive strength.

Table 6
Flexural strength test result

Beam Specimen	Compressive Strength (N/mm^2)		
	1 day	7 days	28 days
0TR	2.403	5.229	6.499
10TR	1.901	3.256	4.025
20TR	1.643	2.651	2.669
30TR	0.860	1.911	2.501

Correlation of flexural strength and percentage of tyre rubber. Table 7 showed the correlation between flexural strength and percentage of tyre rubber. The trend of the result was similar to the compressive strength. For linear correlation, the R^2 value was 0.9603 for 1 day, but dropped to 0.9187 for 7 days and 0.8702 for 28 days. Second-order polynomial correlation on the other hand had a high R^2 value for specimen of all tested age. This proved that the impact of waste tyre rubber to flexural strength was linear at start but grew to second-order polynomial at later age. Both correlations were accurate in expressing the strength of mortar at day 1 but second-order polynomial expression took over as the more suitable expression beyond day 7. This showed that not only did the strength of mortar dropped with more tyre rubber replacement, the rate in which the strength dropped grew with a higher replacement percentage. Hence, the replacement of sand with tyre rubber must be done sparingly.

Table 7
Correlation of flexural strength and percentage of tyre rubber

Mortar Age	Linear Correlation		Second-Order Polynomial Correlation	
	Equation	R^2	Equation	R^2
1 day	$y = -0.049x + 2.43$	0.9603	$y = 0.0007x^2 - 0.028x + 2.36$	0.9902
7 days	$y = -0.11x + 4.85$	0.9187	$y = 0.0031x^2 - 0.20x + 5.15$	0.9979
28 days	$y = -0.13x + 5.93$	0.8702	$y = 0.0058x^2 - 0.31x + 6.50$	0.9999

Flexural strength activity index. Flexural strength activity index was presented in Figure 3. The trend of the index was similar to compressive strength index. The strength index of 10TR was the highest among all tyre rubber mortar up to 28 days, falling between 62% and 79%. Strength index of 20TR was between 62% to 68% while the index of 30TR was below 40%. From the graph, the drop in strength for 10TR was manageable but became very significant beyond 20TR. Hence, tyre rubber replacement beyond 20% was not recommended.

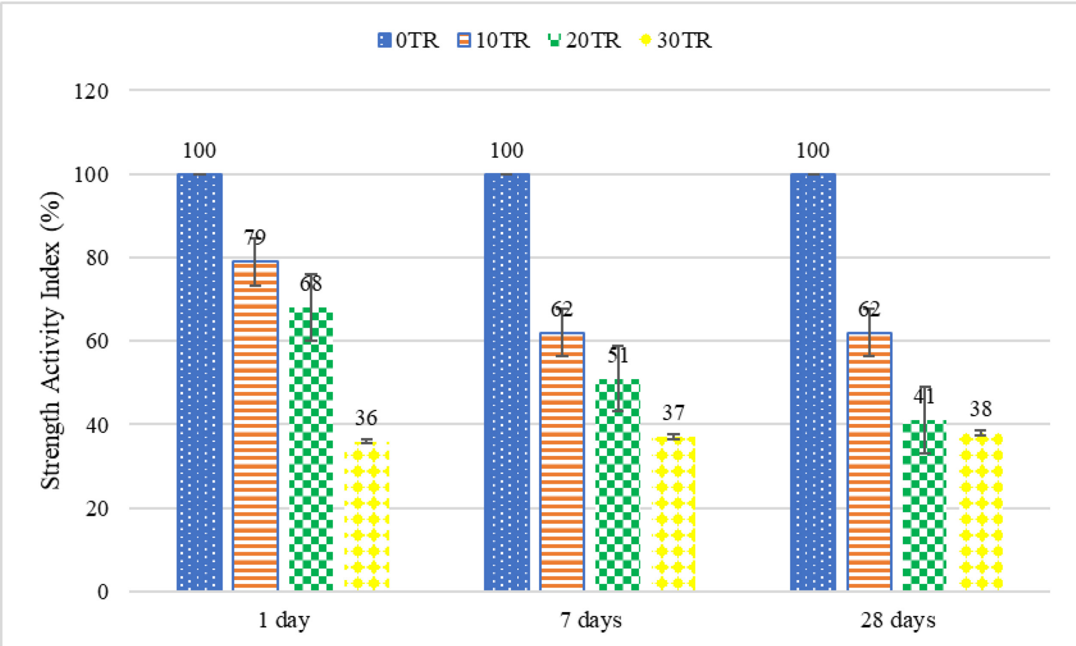

Fig. 3 Flexural strength index of tyre rubber mortar

Relationship between density and strength. Density of mortar specimens were studied as it was another factor that affect its strength. Figure 4 showed the density and strength of mortar specimens at 28 days plotted together. The density of 0TR was 2054 kg/m^3. When waste tyre rubber replaced sand, the density of mortar dropped to 1889 kg/m^3 for 10TR, 1731 kg/m^3 for 20TR, and 1688 kg/m^3 at 30TR. This is to be expected, as tyre rubber has lower density compared to sand. Rubber is also weaker than sand at resisting load due to its elastic nature, hence higher replacement of sand with rubber reduced both density and strength [36]. From the graph, it was observed that the trend of density drop and strength drop was similar. To identify the relationship between density of mortar and strength, a simple regression analysis was conducted, and the result was shown on Table 8. The correlation between density and compressive strength had a R^2 value of 0.9884, while flexural strength had R^2 value of 0.9702. The high R^2 value of both cases signified a strong correlation between density and strength of mortar.

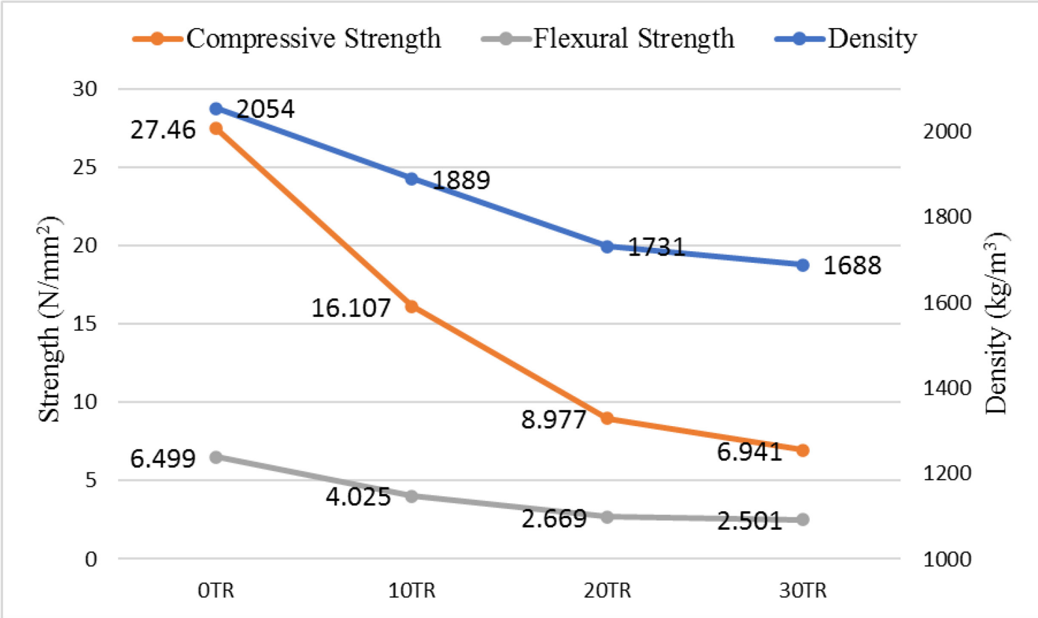

Fig. 4 Density and strength of mortar

Table 8
R^2 value density verses mechanical strength

Density	Compressive strength	Flexural strength
R^2	0.9884	0.9702
Expression	y = 0.055x – 87	y = 0.01x – 16.12
Relationship	Positive correlation	Positive correlation

Water absorption. The 28 days result of water absorption was plotted on Figure 4. The control specimen had a water absorption rate of 7.58%. 10TR and 20TR had lower rate of water absorption compared to control, which was 7.50% and 7.36% respectively. However, a huge increase in water absorption was observed at 30TR with the rate of 8.77%. At up to 20%, replacement of sand with tyre rubber helped to reduce water absorption. Fine tyre rubber with the size between 300nm and 500nm acted as a good filler to improve the pore structure of mortar. While such nanoscale size was not previously tested, result from similar researches agreed that replacement of sand with tyre rubber could reduce water absorption [12], but the water absorption increased when the replacement went beyond 35% [27]. Specimen 30TR has the highest rate of water absorption than others due to the pores created by the tyre particles during hydration process [37]. As the tyre waste is too light and tends to float on the wet mixture in fresh state, its elastic behavior results in poorly compaction and thus more voids in the specimen [38]. Correlation between water absorption with compressive and flexural strength could not be established because the strength of mortar specimens decreased with tyre rubber replacement while water absorption varied.

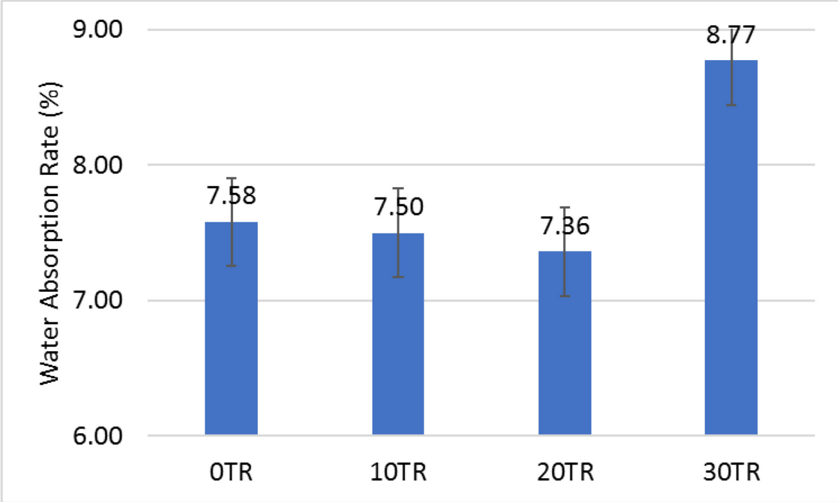

Fig. 5 Water absorption of tyre rubber mortar

Acid attack. The mass loss of acid attack on mortar specimens was presented on Figure 6. After 28 days in sulphuric acid solution, the control specimen measured a 0.431% loss of mass. The mass loss of mortar was reduced to 0.339% with 10% tyre rubber, and the least among of loss was measured at 20% tyre rubber, which was only 0.114%. However, at 30% tyre rubber replacement, the mass loss of mortar specimens increased again to 0.201%. The compressive strength loss of mortar specimen was presented on Figure 7. The control specimen gained 0.624% strength after 28 days in sulphuric acid solution. On the other hand, specimens with tyre rubber gained more strength across the duration, with 10% tyre rubber specimen gaining 3.362% strength and 20% tyre rubber speicmen gaining 12.355% strength. This occured as the specimens were still undergoing the curing process after 28 days. However, it was apparent that 20% tyre rubber provided the best resistance to acid attack due to the high amount of strength gained. At 30% tyre rubber, the mortar specimen lossed 11.81% strength. Similar to the result of water absoption, the replacement of sand with tyre rubber improved the filling properties of mortar, minimising the penetration of acidic solution and hence the damage to concrete. In addition, rubber particles were resistance to acid [39] and durable in aggresive environment [40]. The presence of rubber particles also prevented the constituent material from breaking away by minimising the cracking of mortar with its elastic nature [19]. As a result, rubberised mortar showed superior durability at 20% tyre rubber replacement. Beyond the optimal replacement however, the cohesion between the materials was compromised and poor microstruture reduced the quality of mortar.

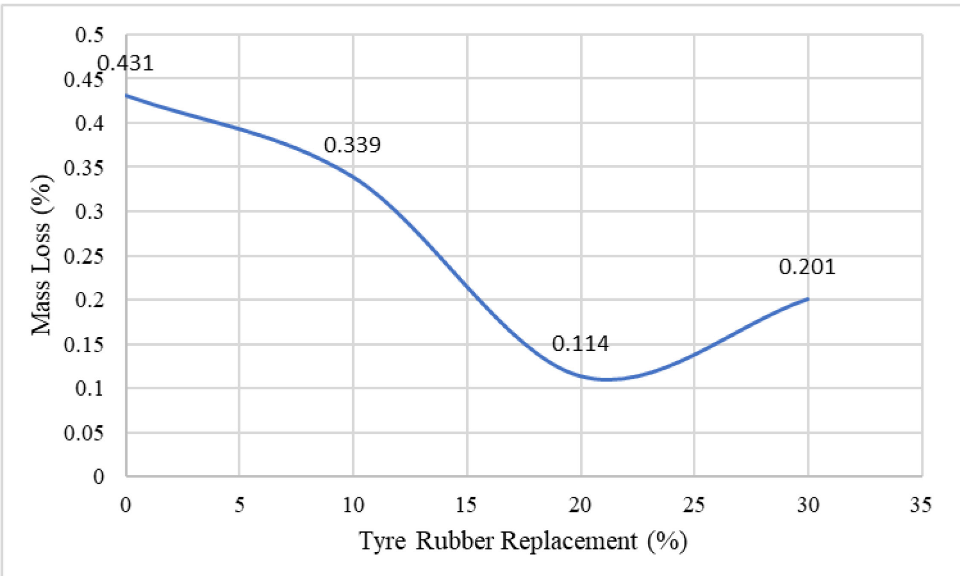

Fig. 6 Mass loss of tyre rubber mortar

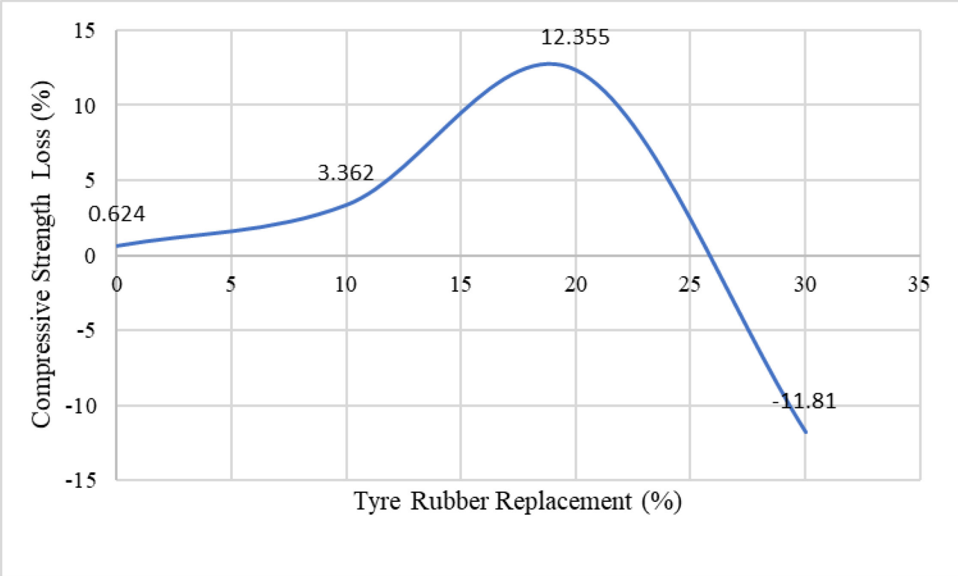

Fig. 7 Compressive strength loss of tyre rubber mortar

Conclusion

This paper studies the properties of mortar with fine rubber powder as partial sand replacement. It can be concluded that rubber powder reduced the consistency of mortar and require additional water. Replacemen of sand with rubber also reduces the density of mortar. The control specimen had a density of 2054 kg/m^3 but the density dropped to 1688 kg/m^3 for 30% tyre rubber. Waste tyre rubber reduced compressive and flexural strength of mortar. The reduction happened in a linear function at early age and second-order polynomial function beyond 7 days. Mortar with up to 20% tyre rubber achieved desired strength despite the drop while 30% tyre rubber failed to achieve the target. Mortar with rubber replacement had lower water absorption and higher resistance to acid attack at up to 20% tyre rubber due to the superior filling effect of fine grinded rubber. However, durability of mortar with 30% rubber was compromised due to poor bonding between rubber and cement paste. As a conclusion, mortar with 20% tyre rubber is a viable green material for construction work in the future.

Acknowledgement

This study was supported by the Malaysian Ministry of Higher Education and Universiti Malaysia Pahang under the research grant (RDU/UMP) vote number RDU190339.

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