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EFFECT OF RUBBER POWDER PARTICLE ON THE STRENGTH OF FOAMED CONCRETE

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ABSTRACT: Foamed concrete has become one of the most commercialized materials used in construction industry. It has different characteristics compared to conventional concrete such as self-compacting without vibration, flowability and low density. Even though foamed concrete has many advantages but it possess low strength limiting its use in many applications. This research aims to investigate the potential of foamed concrete incorporating rubber powder as additive to improve its strength. The amount of rubber powder added as filler in foamed concrete are 0%, 3%, 6%, 9% and 12%. A total of 15 concrete cubes and 15 concrete cylinders were cast with difference percentages of rubber powder in order to evaluate its compressive and splitting tensile strength. The mix design was set to achieve a density of 1800 kg/m^3. The experiments on fresh state properties show that the foamed concrete has a very low workability as the percentage of rubber increase. However, the compressive and splitting tensile strengths for foamed concrete containing rubber are higher compared to control foamed concrete. The addition of 9% of rubber brought a significant increase for compressive strength and tensile strength of 122% and 43%, respectively, as compared to foamed concrete without rubber powder. Based on the results, it was concluded that the optimum percentage of rubber in this research was 9% for the highest compressive and tensile strength for foamed concrete.

Keywords: Rubber powder, Foamed concrete, Compressive strength, Split tensile strength.

1. INTRODUCTION

Foamed concrete is a versatile material due to its advantages such a lightweight, high flowability, serviceability and sufficient durability to be used either in structural or non-structural applications. The development of foam concrete is to reduce the rate and cost of construction, and at the same time to reduce the consumption of raw materials. The mix of foamed concrete consists of mortar, and foaming agent to produce approximately 25% air void, both contribute to the lightness of the concrete [1].The density of foamed concrete ranges from 300 kg/m^3 to 1800 kg/m^3 with a compressive strength and tensile strength of up to 10 N/mm^2 and 1.6 N/mm^2, respectively [2]. With much lower strength as compared to normal concrete, the application of foamed concrete are limited. Hence, there are many attempts that have been made to improve the properties by incorporating natural, artificial and rather recycled material as additive in foam concrete.

The properties of foamed concrete incorporating various materials such as fly ash, lime and polypropylene either as cement replacement or additive have been studied by Awang et al. [3]. The results showed that the abovementioned materials did not contribute to the compressive strength of the concrete, but an improvement in the tensile strength was recorded. Fly ash as cement replacement, however, improved the compressive and tensile properties of foam concrete. Some of the material such as polypropylene fibre produces more pores which significantly affect the compressive strength. Similar trend in compressive strength reduction also reported by Wan Ibrahim et al. [4] using polyolefin fiber. Polyolefin fiber however improved the tensile properties of the foam concrete as it delays the crack propagation in concrete.

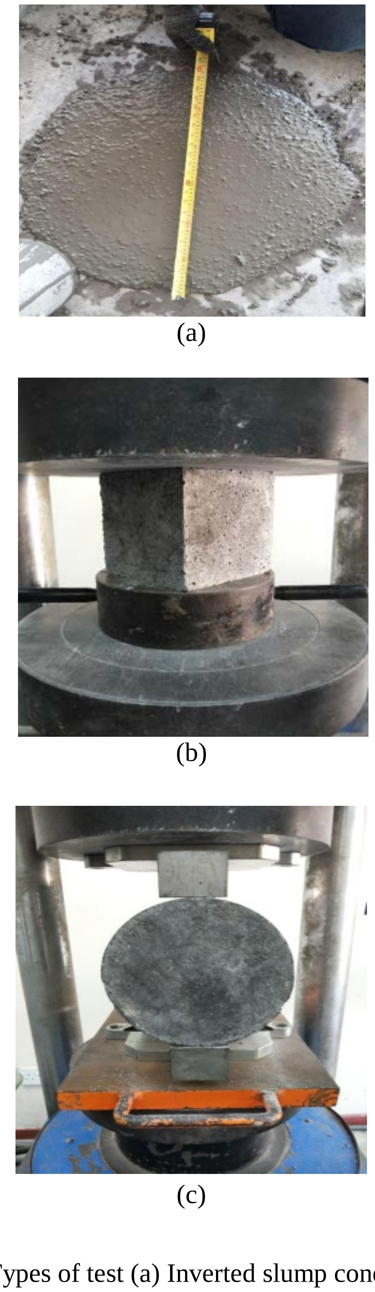
Apart from fly ash and fibre materials used either as replacement or additive, the usage of scrap tires has gained interest into research worldwide due to its abundance [5]. In Malaysia, the Ministry of Transport recorded about 25 million vehicles to be registered included 1.2 million new vehicles in the year 2014 [6], and this number is expected to increase every year. Recycled tire in the form of powder as the result of pyrolysis treatment turns into household product and also dumped into landfill as this process brings low environmental impact. Rubber powder has been used as binder in bitumen and provides greater strength as compared to normal bitumen in road industry [7]. This material can be utilized as construction material in concrete either as replacement or additive. The results obtained by Chitra et al. [8] and Abdullah et al. [9] are quite promising where improvement in some properties are identical with normal concrete in terms of its strength. It has been suggested that with a few adjustment and modification, the use of rubber powder may be beneficial for sustainable construction. Under microscopic examination, it shows that inclusion of 5% rubber powder reduced 85% pore size of concrete compared to concrete without rubber powder [8]. However, its suitability to be used in foamed concrete has not been studied earlier. Due to their very fine size with a specific gravity of 2.21, the rubber used [10] as a filler to fill the void is expected to increase the strength of foamed concrete. Therefore, this study aims to assess the potential use of rubber powder as an additive in foam concrete.

2. EXPERIMENTAL DETAILS

The cement used in producing the foamed concrete was ordinary Portland cement (OPC). Pre-forming method was applied to produce foamed concrete. The method was conducted by using suitable foaming agent that mix together with water, and then foam is combined with paste or mortar. Cement, sand and water were basic materials mixed to form mortar while the stable preformed foam was produced separately. Foam was produced by using a foaming agent generator. Foaming agent contained a blend of synthetic surfactant and polymer was used in this study. The ratio of foaming agent diluted with water was 1:20. Sand passing through 2.0 mm was used in this study.

The rubber powder (Fig. 1) obtained from the pyrolysis industry having a maximum size of 2mm used in the study [11]. Rubber powder from pyrolysis industry having a specific gravity of 2.17, bulk density of 641.48 kg/m^3, both has lower value compared to sand [12], make it suitable to be used as filler in concrete. The mix proportion of foam concrete with varying percentage of rubber powder (0-12%) as additive by the total volume of concrete was produced. Foamed concrete was set to achieve density 1800 kg/m^3 and water cement ratio was kept constant at 0.55. At fresh state of foamed concrete, the inverted slump cone test was conducted in accordance with BS EN12350-8:2010 [13] to observe the flowability of foamed concrete (Fig 2a). For hardened state, a total of sixty sample consisted 100mm concrete cubesand concrete cylinder of 150 mm x 300 mm were cast to determine compressive and splitting tensile strength, respectively as described in BS EN 12390-3[14] and BS EN 12390-6 [15](Fig 2b and 2c).

Fig.1 Rubber powder used in the test



(a)

(b)

(c)

Fig. 2 Types of test (a) Inverted slump cone, (b) Compression and (c) Splitting tensile

3. RESULTS AND DISCUSSIONS

3.1 Workability

The workability of foamed concrete mixes is measured by diameter of the slump flow. Figure 3 demonstrates that the workability of foamed concrete decrease due to increasing of rubber content. For a control specimen, the spread of slump diameter is 68 cm. For foamed concrete containing rubber, the slump flow diameter decreased as the percentage of rubber increased. The values of slump flow diameter of all foam concrete mixes containing rubber do not conform to the standard value which is in the range of 60cm to 80cm. The increase in the rubber content decreased the workability of the mixture, hence reduce slump flow diameter of the foamed concrete.

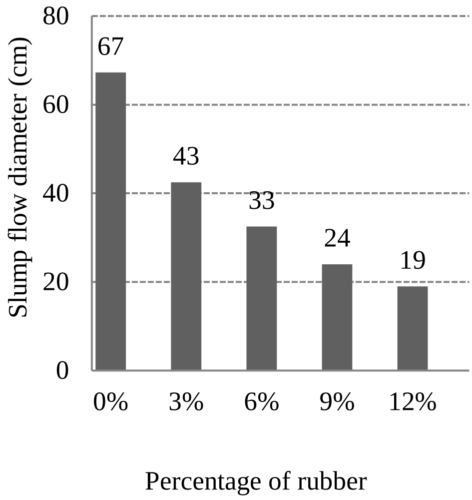


Fig.3 Workability of foamed concrete containing rubber powder

3.2 Compressive Strength

Compared to the normal foamed concrete, inclusion of rubber powder generally improved compressive strength of foamed concrete. Figure 4 shows the average compressive strength of foamed concrete mixes with different percentages of rubber at 7 and 28 days. It is observed from the figure that the compressive strength for the control sample and rubber mixes have a continuous strength development at both testing ages except for the mix containing 12% rubber.

At testing age of 28 days, the strength of control specimen is 12.7 N/mm^2. Inclusion of rubber which acts as filler or additive improved the strength of concrete by 75% to 122%.The strength of foamed concrete with 6% and 9% rubber have attained almost similar result recorded at 29.9 N/mm^2 and 28.3 N/mm^2, respectively. However, for 12% rubber, the strength reduced tremendously at 21.4 N/mm^2 compared to the to the 6 and 9% rubber. By increasing the amount of rubber powder of more than 9% gradually reduced the compressive strength of foamed concrete. This phenomenon may be due to additional number of pores is produced due to excessive amount of rubber in foamed concrete. This has been supported by the test where optical microscopic showed that bonding between rubber powder and cement paste was poor, hence reduced the compressive strength of foamed concrete [16]. Apart from that, higher content of rubber attribute to development of micro crack which affects the compressive strength of concrete [17].

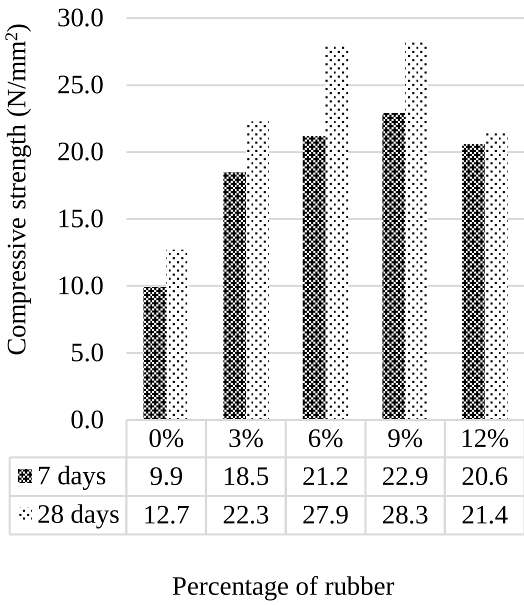
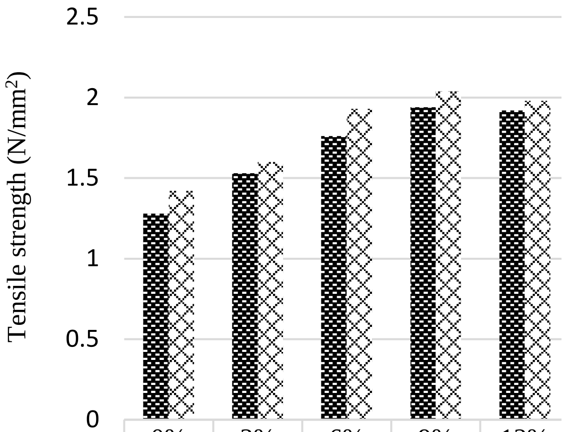


Fig.4 Compressive strength at 7 and 28 days

3.3 Split Tensile Strength

Data in Figure 5 clearly shows the presence of rubber steadily increased the splitting tensile strength of foam concrete at both testing ages. This increase in tensile strength ranged from 12% to 43% as compared to control specimen at 28 days. It is interesting to note that beyond 9% of rubber content, the strength is slightly reduced. At 28 days, the tensile strength increase from 1.4 N/mm^2 (0%) to 2.0 N/mm^2 (9% rubber), and reduced slightly to 1.98 N/mm^2 (12% rubber). In general, it can be said that the fine rubber particles have a better void filling ability and that may help increasing the tensile strength [18]. In addition, rubber produced effective packing structures particularly in the interfacial zone hence making it more homogenous that significantly increase the strength of foamed concrete [10].

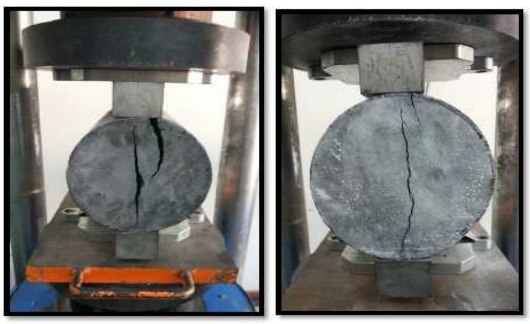
This is to note that the failure of control specimen was more brittle characteristics with larger crack at peak load as compared to foamed concrete with rubber (Fig. 6). For foam concrete with rubber, the number and size of crack appeared was lesser than the control specimen. This observation indicates great deformability of foamed concrete with rubber which has plastic nature compared to control specimen [19].



	0%	3%	6%	9%	12%
7 days	1.28	1.53	1.76	1.94	1.92
28 days	1.42	1.6	1.93	2.04	1.98

Percentage of rubber

Fig. 5 Splitting tensile strength at 7 and 28 days



(a) Normal (b) With rubber

Fig. 6 Failure modes of cylinder specimen

3.4 Relationship between splitting tensile strength and compressive strength

It is important to study the ratio of tensile strength to compressive strength of foamed concrete. In general, increase in the compressive strength of concrete, increased in the splitting tensile strength. The ratio of splitting tensile strength is reduced as the compressive strength increased (Table 1). This was in line with the findings by previous researchers on various types of concrete such as normal, geopolymer and self-compacting concrete. [20-28]. Although the findings in this study somewhat contradict with the finding of Hilal et al, [29], improvement in the tensile properties containing rubber is closely linked with the better structural properties of concrete such as shear resistant, bond strength and cracking resistant [30].

A relationship between splitting tensile and compressive strength is plotted as in Fig 7. Using the statistical line of best fit, and with correlation and regression analysis, a relevant empirical expression can be presented as Eq.(1):

$$\mathbf{f_{sc} = 0.5 f_c^{\,0.4}} \tag{1}$$

Where f_{sc} = splitting tensile strength and
f_c= compressive strength

Table 1 Ratio of splitting tensile strength to compressive strength

Rubber (%)	f_c	f_{sc}	Ratio f_{sc}/f_c
0	12.7	1.4	0.11
3	22.3	1.6	0.07
6	27.9	1.9	0.07
9	28.3	2.0	0.07
12	21.4	2.0	0.09

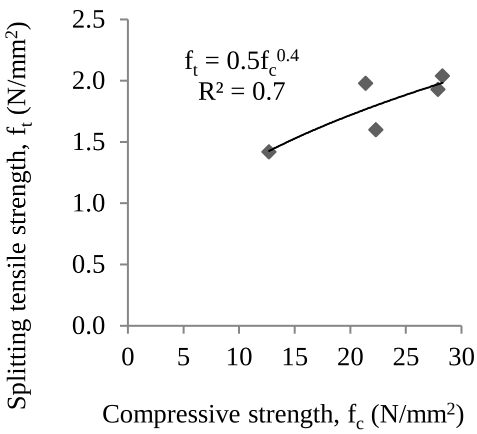


Fig. 7 Relationship between splitting tensile strength and compressive strength

4. CONCLUSION

The inclusion of rubber in foamed concrete affected the flow properties of concrete. The flowablity of foamed concrete was decreased as the percentage of rubber increased. This behavior was due to fact that rubber particles make the foamed concrete difficult to mix. The use of superplasticizer may improve the flowability of foam concrete with rubber.

Despite lower workability, the addition of rubber in foamed concrete helped increasing the compressive strength by 75%-122% compared to control sample. In term of tensile strength, enhancement by 12%-43% was recorded for foamed concrete with rubber. The improvement of strength, however, has been limited to the maximum amount of 9% rubber.

Results obtained and the observation made in this study suggest that rubber powder has the potentials to be used in foamed concrete to improve the strength. Long-term investigation with suitable admixture, like superplastisizer has been proposed as recommendation for future study in order to improve workability and strength as well.

5. REFERENCES

[1] Thakrele, M.H. (2014). Experimental study of foam concrete, International Journal of Civil Structural, Environmental and Infrastructure Engineering Research and Development, Vol.4,No.1, pp.145–158.

[2] Barnes, R.A., Foamed concrete: Application and Specification, Concrete Construction Excellence in concrete construction through innovation, pp. 3-10, Francis Ltd, Boca Raton, London, Taylor, 2009.

[3] Awang, H., Mydin, M.A.O and Roslan, A.F. (2012). Effect of additives on mechanical and thermal properties of lightweight foamed concrete, Advances in Applied Science Research, Vol.3,No.5 pp. 3326-3338.

[4] Ibrahim W. M. H, Jamaludin N, Irwan J.M, Ramadhansyah P.J, and,Suraya Hani A. (2014).Compressive and Flexural Strength of Foamed Concrete Containing Polyolefin Fibers, Advanced Material Research, Vol. 911, pp. 489 -493, Trans Tech Publications, Switzerland.

[5] Bekhiti, M., Trouzine, H. and Asroun, A. (2014). Properties of Waste Tire Rubber Powder, Engineering, Technology & Applied Science Research, Vol. 4, No. 4, pp.669-672.

[6] Ministry of Transport (2015), Transport Statistic Malaysia, ISSN 01282778.

[7] Pasalkar, A. A, Bijaj, M. Yogesh, Wagh, A. Amol and Dalvi, Jitendra, D. (2015). Compressive Literature Review on use of Waster Tire Rubber in Flexible Road Pavement. International Journal of Engineering Research & Technology. Vol. 4. No.2. pp. 685-689.

[8] Chitra, G., Selvi, P.V. andVijayalakshmi, D. (2014). Carbon Black as an Additive in Conventional Concrete. International Journal of Emerging Technology and Advanced EngineeringVol.4, No.3. pp. 194-201.

[9] Abdullah, S.R., Zainal, W.W.R and Shahidan,S. (2016). Strength of concrete containing rubber particle as cement replacement, MATEC Web of Conference, Vol.47, 01009.

[10] AkhrasN.M. and Smadi M.M. (2004). Properties of tire rubber ash. Cement and Concrete Composite, Vol. 26. pp. 821-826.

[11] Shahidan, S., Senin, M.S.,A.Ghaffar, N., Ali, N. and RamziHanan, N.I.R. The effect on different substitutes of rubber cement mortar. 13th International Conference on Concrete Engineering and Technology, 31 May-June 2016, Selangor, Malaysia.

[12] Senin, M.S., Shahidan, S., Leman, A.S. and RamziHanan, N.I.R. (2016). Analysis of physical properties and mineralogy of pyrolysis tire rubber as compared natural sand in concrete material. International Engineering Research and Innovation Symposium. *IOP* Conf. Ser.: Mater. Sci. Eng. *160 012053.*

[13] BS EN12350-8 Self-compacting concrete- slump flow test British European Standards Specifications 2010.

[14] BS EN 12390-3 Testing hardened concrete: Compressive strength of Test Specimen. British European Standards Specifications, 2002.

[15] BS EN 12390-6 Testing hardened concrete: Tensile splitting strength of test specimen. British European Standards Specifications, 2000b.

[16] Chen, C.J,Tang, Y.M,Tseng, S.S,and Wang, H.Y., A Study of the engineering properites on concrete with the application of pozzolanic material and waste tire rubber powder. Proceeding the 6th Civil Engineering Conference in Asia Region: Embracing the Future through Sustainability. 20 - 22 August, 2013.pp.55-63.

[17] Akinyele, J.O., Salim, R.W. and Kupolati, W.K. (2016). Effect of crumb rubber on microsctructural properties of concrete. African Journal of Science, Technology, Innovation and Development, 8, 5-5, pp. 467-474.

[18] Chitra, G., Selvi,P.V and Vijayalakshmi, D.(2014). Carbon black as an additive in conventional concrete. International Journal of Emerging Technology and Advanced Engineering, 4(3), pp. 456-461.

[19] Skripkuinas, G., Grinys, A. and Cermius, B. (2007). Deformation properties of concrete with rubber waste additive. Material Science, 13, 3, pp 219-223.

[20] Arioglu, N., Girgin, Z.C. and Arioglu E. (2006). Evaluation of ratio between splitting tensile strength and compressive strength for concrete up to 120MPa and its application in strength criterion. ACI Material J., 103 (1), pp. 18-29.

[21] Lavanya, G., and Jegan, J. (2015). Evaluation of relationship between split tensile strength and compressive strength for geopolymer concrete of varying grades and molarity. International Journal of Applied Research, 10, 15, pp. 35523-35527.

[22] Akinpelu, A. M., Odeyemi, S.O., Olafusi, O.S. and Muhammed, F.Z. (2017). Evaluation of splitting tensile and compressive strength relationship of self-compacting concrete. Journal of King Saud University- Engineering Science. http://dx.doi.org/10.1016/j.jksues.2017.01.005

[23] Awal, A.S.M.A.(1988), Failure mechanism of prepacked concrete, Journal of Structural Engineering, ASCE, Vol.114, No.3, pp.727-732.

[24] Hossain, M.Z. and Awal, A.S.M.A.(2011), Experimental validation of a theoretical model for flexural modulus of elasticity of thin cement composite, Construction and Building Materials, Vol. 25, No. 3, pp.1460-1465.

[25] Shehu, I. A. and Awal, A.S.M.A. (2012). Mechanical properties of concrete incorporating high volume palm oil fuel ash, Advanced Materials Research, Trans Tech Publications, Vol.599, pp.537-540.

[26] Awal,A.S.M.A. and Shehu, I.A.(2015). Performance evaluation of concrete containing high volume palm oil fuel ash exposed to elevated temperature, Construction and Building Materials, Vol.76, pp.214-220.

[27] Awal, A.S.M.A., Kadir, M. A. A., and Hossain, M.Z. (2016). Some aspects of physical and mechanical properties of sawdust concrete, International Journal of GEOMATE, Vol.10, No.21, pp.1918-1923.

[28] Awal, A.S.M.A., Ibrahim, M.H.W, Ali, A.Z.M. and Hossain, M.Z. (2017). Mechanical properties and thermal behaviour of two-stage concrete containing palm oil fuel ash, International Journal of GEOMATE, Vol.12, No.32, pp.166-175.

[29] Hilal, A.A, Thom, N.H.,and Dawson, A.R. (2015). The use of additive to enhance properties of pre-formed foamed concrete. International Journal of Engineering and technology, 7,4, pp286-293.

[30] Babu, D. Mechanical and deformation properties, and shrinkage cracking behaviour of lightweight concrete. PhD Thesis, Department of Civil Engineering. National University of Singapore, 2008.