Recent Trends in Civil Engineering and Built Environment Vol. 3 No. 1 (2022) 420-426
© Universiti Tun Hussein Onn Malaysia Publisher's Office

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

Energy Absorption of Modified Rubberized Concrete Block Under Low Velocity Impact Loads

Masidayu Abdul Kadir[1], Shahrul Niza Mokhatar [2]*, Nur Anis Najwa Abd Mutalib[1]

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA

[2]Structural Dynamics and Computational Engineering Focus Group,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rtcebe.2022.03.01.044
Received 4 July 2021; Accepted 13 December 2021; Available online 15 July 2022

Abstract: Concrete road barriers are widely used for safety by separating traffic in opposite directions. However, when subjected to impact loads such as road accidents, the road barrier can only absorb slight energy. This study intends to investigate energy absorption of modified rubberized concrete under low velocity impact loads. The design of the concrete mix containing treated and untreated crumb rubber (CR), the prediction of the modified rubberized concrete (MRC)'s penetration depth and its energy absorption was studied. The size of MRC blocks are 300 mm × 300 mm × 200 mm for seven (7) specimens, which are one (1) control (0% CR, 0%RHA), three (3) untreated CR (5% + 10% RHA, 10%+ 10% RHA, 15% + 10% RHA) and three (3) treated CR (5% + 10% RHA, 10%+ 10% RHA, 15% + 10% RHA) were design. Initially, the penetration depth was obtained from previous study and the projection of its energy absorption were then calculated using the empirical formula. From the result, it is proven that using MRC blocks with 15% treated CR is the optimum choice to be applied to produce the road barrier.

Keywords: Treated and Untreated Crumb Rubber, Concrete Mix, Penetration Depth, Energy Absorption

1. Introduction

The conventional concrete is used for all purposes as the concrete not only hold up normal loading such as weight, but also can resist the impact loading due to eruption or ballistic effect [1]. Concrete properties being modified by the inclusion of appropriate waste substances is a popular field in concrete research area [5]. In this study, waste tire particles which is crumb rubber (CR) is selected as the substitution of fine aggregate to feasibly remedy or the solution for its shortcomings [1]. The reason why CR is chosen because of its elasticity characteristic. In addition, CR is deformable particles that

*Corresponding author: shahruln@uthm.edu.my

could improve certain concrete properties [6]. Besides, 10% Rice Husk Ash (RHA) is also used as cement replacement in Modified Rubberized Concrete (MRC). The presence of RHA in concrete escalate the strength of MRC [1]. In order to reduce damaging and some are lethal accidents with the road barrier, modification of the road barrier is needed in terms of altering its element [10]. The impact severity between vehicles and road barrier have resulting many casualties and damages to vehicles and as the years passed by, the number of victims continued to rise. Therefore, to minimal the harm, MRC is created to improve the performance of conventional concrete in terms of plasticity and energy absorption when it is subjected to impact loads [7]. The modification of the MRC by the addition of RHA will increased the compressive strength of the concrete and increase the penetration depth of the MRC when subjected to impact loads. The objective of this study are to design the concrete mix containing treated and untreated CR as well as to predict the energy absorption of modified rubberized concrete by utilizing empirical formula.

This project involves the design of the concrete mix containing treated and untreated CR and prediction of penetration depth of the MRC blocks. Three (3) specimens with different percentage (5%, 10%, and 15%) of untreated CR and 10% RHA, three (3) specimens with different percentage (5%, 10%, and 15%) of treated CR and 10% RHA, and a specimen with 0% for CR and 0% for RHA act as control were prepared. The CR were soaked into sodium hydroxide (NaOH) solution with 1 mol concentration to produce treated CR. The untreated and treated CR were replaced by volume for fine aggregate and the RHA were replaced by mass for the cement. As for the design of the concrete mix, before the fabrication of the MRC blocks can be done, the materials needed are calculated using concrete mix design form. The dimensions of the MRC blocks are 300 mm × 300 mm × 200 mm [2]. The data obtained which is the penetration depth using prediction from the previous study and it was analyzed using the empirical formula [1]. The prediction made in this study are based on the previous research findings by Mokhatar et al., [2].

2. Materials and Method

The materials composition for concrete mix are shown in Table 1. Materials such as cement, water, fine aggregate and coarse aggregate were obtained from the concrete mix design form and 2 kg of sodium hydroxide pellets were needed to treat the CR. The dimension of MRC block as illustrated in Figure 1. The length and width of the block is 300 mm and its height is 200 mm, respectively.

The length of the block is 300 mm, width is 300 mm and height 200 mm.

Table 1: Material composition

Material	Total (kg)
Cement:	405
Water:	190
Fine Aggregate:	760
Coarse Aggregate:	1045
Sodium Hydroxide (NaOH):	2.0000

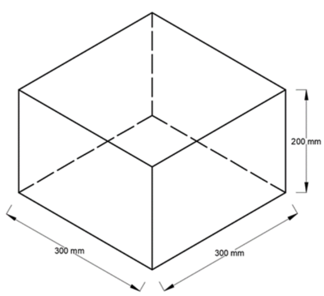

Figure 1: Dimension of the MRC block

For each specimen, the specific amount of cement, water, fine aggregate, coarse aggregate, RHA, and treated and untreated CR were calculated using the information from Table 1. NaOH was used to soak CR and were calculated. The percentage of untreated and treated CR as well as RHA are shown in Table 2.

Table 2: CR and RHA percentages for each specimen

Specimen	CR percentage	RHA percentage
A	0%	0%
B	5% untreated CR	10%
C	10% untreated CR	10%
D	15% untreated CR	10%
E	5% treated CR	10%
F	10% treated CR	10%
G	15% treated CR	10%

Figure 2 depicted the graph of MRC block with untreated CR against penetration depth. The curve was plotted based on previous study data and the trend line of the graph were extended.

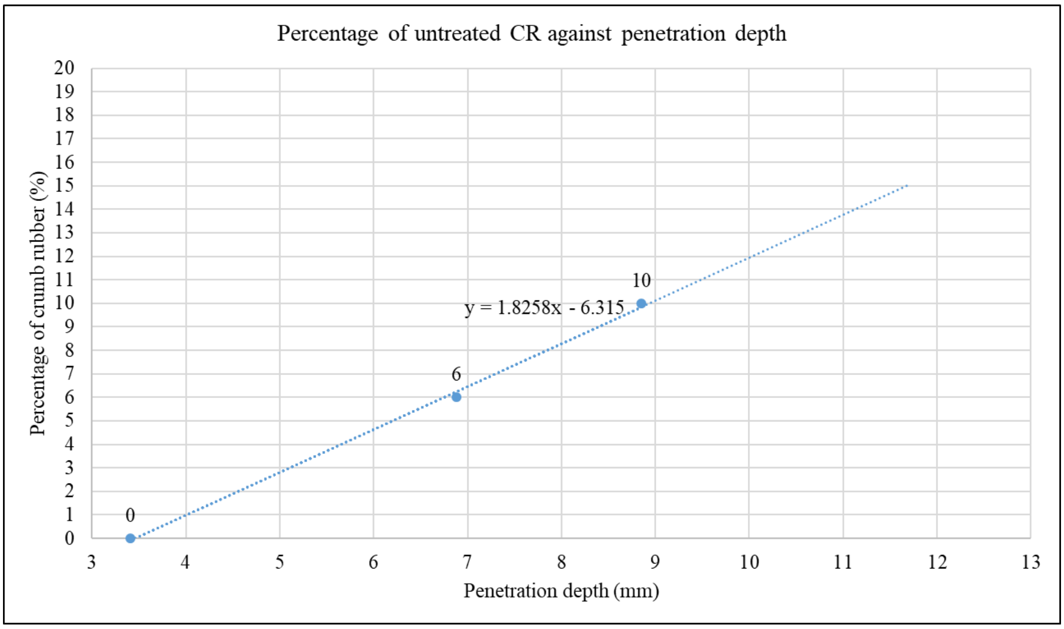

Figure 2: Graph percentage of CR against penetration depth

The equation (1) is produced from Figure 2, and rearranged accordingly to produce equation (2). Both equations used to predict the penetration depth pf MRC with untreated CR, where Y denoted as the percentage of untreated CR and X is the penetration depth of MRC with untreated rubber.

$$Y = 1.8258X - 6.315 \qquad Eq, 1$$

$$X = \frac{Y+6.315}{1.8258} \qquad Eq. 2$$

Next, based on the penetration depth of untreated CR data, the penetration depth for treated CR can be also predicted accordingly. Based on the previous study, MRC with treated CR exhibit 5% higher performance. Thus, the penetration depth for the MRC blocks with treated CR can be determined using equation (3). Z is denoted as the penetration depth of MRC with treated CR.

$$Z = 1.05X \qquad Eq.3$$

The energy absorption was calculated using the empirical formula as stated in equation (4). Ea is denoted as energy absorption. The impact force released by the impactor as expressed in the experimental study are from the steel weight, which is equal to 80 kg. the acceleration of earth's gravity is 9.81 m/s^2 and X can be denoted as penetration depth.

$$E_a = m.g.X \qquad Eq.4$$

2. Results and Discussion

The design of the concrete mix for the MRC blocks containing different percentages of CR and RHA were calculated and tabulated as in Table 3.

Table 3: The design mix result for each MRC blocks

Specimen	No. of Spe.	Type of Crumb Rubber	CR Percentage, %	Cement, kg	Water, kg	F. Agg., kg	C. Agg, kg	RHA, kg	CR, kg
A	1	-	0	8.748	4.104	16.416	22.572	0.000	0.000
	3			26.244	12.312	49.248	67.716	0.000	0.000
B	1	Untreated CR	5	7.873	4.104	15.595	22.572	0.875	0.303
	3			23.620	12.312	46.786	67.716	2.624	0.908
C	1		10	7.873	4.104	14.774	22.572	0.875	0.605
	3			23.620	12.312	44.323	67.716	2.624	1.816
D	1		15	7.873	4.104	13.954	22.572	0.875	0.908
	3			23.620	12.312	41.861	67.716	2.624	2.724
E	1	Treated CR	5	7.873	4.104	15.595	22.572	0.875	0.303
	3			23.620	12.312	46.786	67.716	2.624	0.908
F	1		10	7.873	4.104	14.774	22.572	0.875	0.605
	3			23.620	12.312	44.323	67.716	2.624	1.816
G	1		15	7.873	4.104	13.954	22.572	0.875	0.908
	3			23.620	12.312	41.861	67.716	2.624	2.724

Every specimen was calculated according to the size of MRC block which is 300 × 300 × 200 mm. The design mixes for each specimen were considered 20% materials getting stuck in the concrete mixer machine. The density of sand and CR is essential to calculate the CR replacement for fine aggregate by volume. The CR was replaced by volume rather than mass due to the CR are much lighter. Meanwhile, the 10% RHA was used as cement replacement by mass. Each of the specimen were prepared for three (3) samples. Throughout the fabrication process, it is shown that treated CR mixes absorb water much quicker than the untreated mix due to its chemical treatment method.

The result for the penetration depth of MRC blocks with untreated CR were calculated using equation (2), while for MRC blocks with treated CR were calculated using equation (3). All results were as recorded in Table 4.

Table 4: Penetration depth of MRC blocks with untreated and treated CR

Percentage of CR (%)	Penetration depth of untreated CR (mm)	Penetration depth of treated CR (mm)
5	6.1973	6.5071
10	8.9358	9.3826
15	11.6743	12.2581

The energy absorption of every specimen were calculated using equation (4) by considering the penetration depth value. All results are tabulated in Table 5.

Table 5: Energy absorption of the MRC blocks

Specimen	Type of CR	CR percentage, %	Impact velocity, m/s	Penetration depth of each specimen, mm	Energy absorption, Nm
A	-	0	4.000	3.410	2.676
B	Untreated CR	5		6.197	4.864
C		10		8.936	7.013
D		15		11.674	9.162
E	Treated CR	5		6.507	5.107
F		10		9.383	7.363
G		15		12.258	9.620

Subsequently, two graphs were plotted as presented in Figure 3 and Figure 4, in order to clearly analyze the different percentages of untreated and treated CR effecting the penetration depth and the energy absorption of the MRC blocks.

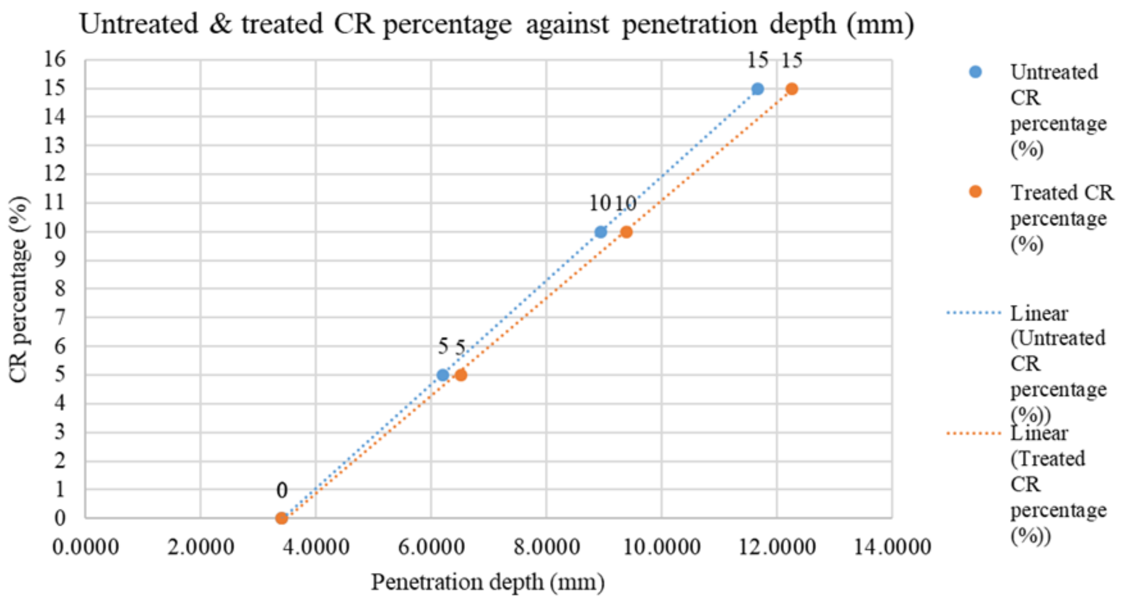

Figure 3: Untreated & treated CR percentage against penetration depth

Figure 3 shown the graph of untreated and treated CR percentage against the penetration depth. This graph was plotted from data obtained in Table 4. In this graph, both of the lines exhibit the increasing linear trend. Both of the penetration depth for the untreated and treated CR were plotted and compared in this graph. The graph proven that MRC blocks using treated CR depicts higher penetration depth than untreated CR. This trend also supported by previous studies that using treated CR with

NaOH. Generally, this treatment method for CR can improve the concrete's performance in term of penetration depth and energy absorption [2], [3] and [4]. It is shown that MRC block with 5% of untreated CR has the lower penetration depth than other percentage of untreated and treated CR which is 6.1973 mm. Meanwhile, the highest penetration depth is MRC blocks with 15% of treated CR about 12.2581 mm. Overall, the lowest penetration was recorded is the conventional concrete with 0% of CR and 0% RHA with only 3.41 mm.

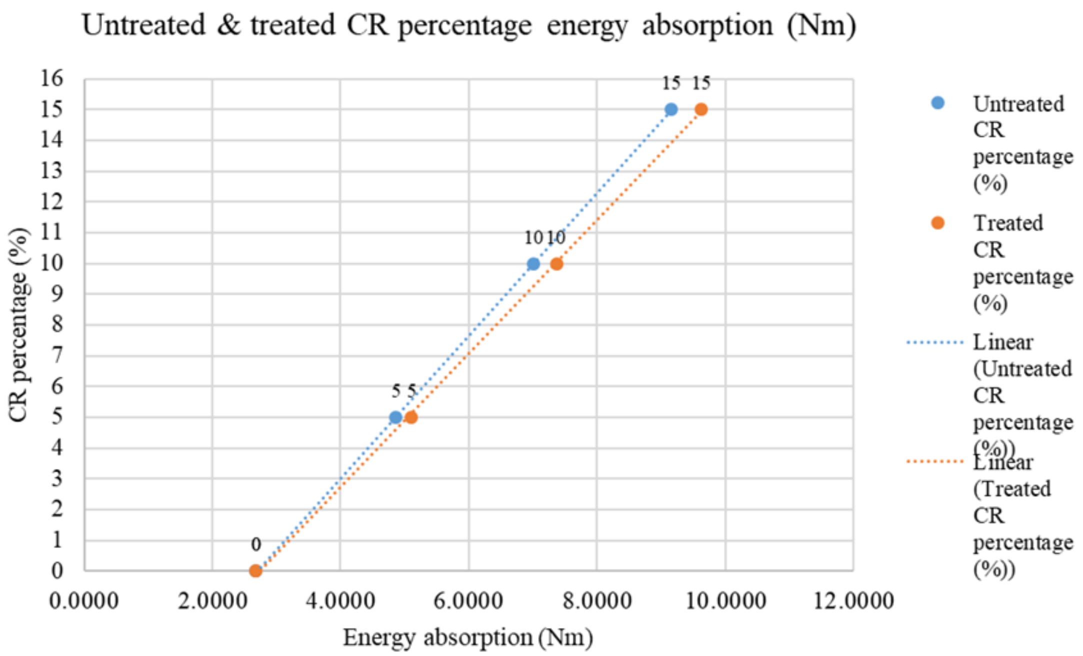

Figure 4: Untreated & treated CR percentage energy absorption

Figure 4 shown the graph of untreated and treated CR percentage against the energy absorption. This graph was plotted from data obtained in Table 5. In this graph, both of the lines exhibit the increasing linear trend as well. Both of the energy absorption for the untreated and treated CR were plotted and compared in this graph. According to the empirical formula for the energy absorption as shown in equation (4), the relationship between the penetration depth and the energy absorption is directly proportional. Therefore, as the penetration depth increase, the energy absorption increase. Hence, the graph exhibits the similar trend as in Figure 3. It is shown that MRC block with 5% of untreated CR has the lower energy absorption than other percentage of untreated and treated CR which is 4.8636 Nm. Meanwhile the highest energy absorption is the MRC blocks with 15% of treated CR with .9.6201 Nm The lowest penetration was recorded is the conventional concrete with 0% of CR and 0% RHA with 2.6762 Nm.

3. Conclusion

The behaviour of the MRC mixes were observed during the fabrication process. It is shown that the MRC mixes with treated CR able to incorporate with other materials better than normal mixes. This is due to the untreated CR still have the zinc stearate layer which carry the role for hydrophobic (repels water) feature of the rubber and made the CR has lower adhesion to other materials in the mixes [8] and [9]. Next, it can be concluded that in order to achieve the highest penetration depth and energy absorption, MRC block with 15% treated CR is the optimum specimen. Thus, the objective to predict the energy absorption of the modified rubberized concrete by utilizing empirical formula were effectively accomplished.

Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Hadipramana, Josef, Abdul Aziz Abdul Samad, Rosziati Ibrahim, Noridah Mohamad, and Fetra Venny Riza. 2016. “The Energy Absorption of Modified Foamed Concrete with Rice Husk Ash Subjected to Impact Loading.” ARPN Journal of Engineering and Applied Sciences 11(12):7437–42.

[2] Shahrul Niza Mokhatar, Nur Anis Najwa Abd Mutalib, Muhammad Asmawi Mohd Ayob, Ahmed Mokhtar Albshir Budiea, Zainorizuan Mohd Jaini, Ahmad Fahmy Kamarudin, and Mohammad Soffi Md Noh. 2021. “Energy Absorption of Concrete Containing Waste Crumb Rubber and Rice Husk Ash (RHA) Under Impact” Malaysian Construction Research Journal 13(2): 142-156.

[3] Assaggaf, Rida Alwi, Mohammed Rizwan Ali, Salah Uthman Al-Dulaijan, and Mohammed Maslehuddin. 2021. “Properties of Concrete with Untreated and Treated Crumb Rubber – A Review.” Journal of Materials Research and Technology 11:1753–98.

[4] Mohammadi, Iman, Hadi Khabbaz, and Kirk Vessalas. 2016. “Enhancing Mechanical Performance of Rubberised Concrete Pavements with Sodium Hydroxide Treatment.” Materials and Structures/Materiaux et Constructions 49(3):813–27.

[5] AbdelAleem, Basem H., and Assem A. A. Hassan. 2019. “Influence of Synthetic Fibers’ Type, Length, and Volume on Enhancing the Structural Performance of Rubberized Concrete.” Construction and Building Materials 229:116861.

[6] Awan, Hamad Hassan, Muhammad Faisal Javed, Adnan Yousaf, Fahid Aslam, Hisham Alabduljabbar, and Amir Mosavi. 2021. “Experimental Evaluation of Untreated and Pretreated Crumb Rubber Used in Concrete.” Crystals 11(5):558.

[7] Elchalakani, Mohamed. 2015. “High Strength Rubberized Concrete Containing Silica Fume for the Construction of Sustainable Road Side Barriers.” Structures 1:20–38.

[8] Guo, Yong Chang, Jian Hong Zhang, Guang Ming Chen, and Zhi Hong Xie. 2014. “Compressive Behaviour of Concrete Structures Incorporating Recycled Concrete Aggregates, Rubber Crumb and Reinforced with Steel Fibre, Subjected to Elevated Temperatures.” Journal of Cleaner Production 72:193–203.

[9] Wang, Jiaqing, Qingli Dai, Shuaicheng Guo, and Ruizhe Si. 2019. “Mechanical and Durability Performance Evaluation of Crumb Rubber-Modified Epoxy Polymer Concrete Overlays.” Construction and Building Materials 203:469–80.

[10] Shen, Weiguo, Chuan Zhang, Zhifeng Yang, Liu Cao, Zhenguo Yang, and Bo Tian. 2014. “Investigation on the Safety Concrete for Highway Crash Barrier.” Construction and Building Materials 70:394–98.