Literature Review on Impact Resistance of Rubberized Concrete with Recycle Coarse Aggregates

Jiawen Chen

University of South Australia, Adelaide, Australia

Email: chenjiawen0405@gmail.com

Abstract

Breakthrough have been made continuously in the field of sustainable materials in the recent decades. The disposal of used tires and crush stones is a major environmental problem causing environmental hazards. Concrete is globally acknowledged as an excellent structural material. As a result, the use of rubber and recycled coarse aggregates in concrete mixing would be an essential research. The literature review focus on the recent research on the properties of recycled coarse aggregates concrete and rubberized concrete. In addition, information of different types of drop weight test would be provided. Furthermore, the key findings of impact resistance of rubberized concrete with recycled coarse aggregate would be identified and recommendations of future search would be made.

1. Introduction

A literature review is made for the research proposal of impact resistance of crumb rubberized concrete with recycled coarse aggregates. Moreover, plenty of journals are read to conduct a well-presented literature review. The environmental concrete in the research consists both rubber and recycled coarse aggregates. However, most of the research focus on crumb rubberized concrete or recycled aggregate concrete separately. The literature review provides the previous tests results for both rubberized concrete and recycled aggregate concrete. Serval different test methods for impact resistance have been developed in recent decades. Moreover, it will be described and compared in this literature review. Furthermore, some recommendations by previous researchers are listed and an exclusive summary of the literature review is made to conduct the key findings to support the research on impact resistance of crumb rubberized concrete with recycled coarse aggregates.

2. The Properties of Recycled Coarse Aggregates Concrete

The environmental impact has been taken into consideration in the field of construction in the recent decades. Recycled materials have been used in the production of concrete. The most common used material to produce coarse aggregate for the production of sustainable concrete is recycled aggregates (Rahal 2007). Recycled aggregates are produced by crushing concrete from the construction site or road pavement. According to the research by Rahal (2007), wasted concrete on the demolished sites constitute the larger resource for recycled coarse aggregates in the Arabian Gulf region. Therefore, it is necessary to have a further study for recycled coarse aggregates. Although most of the research allocate RAC have a decreasing in both compressive strength and elastic modules, the rate of decreasing could be different. According to the research by Ravindraraj, Steward & Greco (2000), the test results indicate 9% decreasing in compressive strength for 100% replacement of coarse aggregates with recycled aggregates. However, the test result from Frondistou-Yannas (1977) indicates 45% decreasing with the same percentage for the replacement of coarse aggregates. Four mixes RCA were produced with 0%, 25%, 50% and 100% replacement of recycled coarse aggregates (Etxeberria et al. 2007). It indicates that the absorption capacity and the humidity level of recycled aggregates could

affect the test result and the humidity level must be high for recycled coarse aggregate. It was found RAC with 100% replacement of recycled coarse aggregates has 20-25% less compression strength than conventional concrete at 28 days with a same effective w/c ratio of 0.5 and cement quantity 325k/m^3. Moreover, medium compression strength 30-45Mpa concrete with 25% replacement of recycled coarse aggregates could achieve the same mechanical properties at 28 days by using same w/c ratio and cement level. To achieve the same mechanical properties at 28 days as the conventional concrete for medium compression strength 30-45Mpa concrete made with 50% and 100% replacement of recycled coarse aggregates, a 5%-10% increasing on cement and 4%-10% decreasing in w/c ratio would be needed. In addition, Chakradhara Rao, Bhattacharyya and Barai (2011) conducted that the improvement in compressive strength of RAC from 28 days to 90 days is not significant, a future study is recommended to be taken on a long-term test for compressive strength. Although the elastic modulus could be lower than conventional concrete, the tensile strength could be higher than the conventional concrete. According to the research by Kwan et al. (2011), the test results show that a "sudden drop" would occur while the replacement of recycled coarse aggregates is higher than 30%. The results that the median of the whisker plot for 60% replacement of recycled coarse aggregates has dropped by 36.7% compared to 30% replacement of recycled coarse aggregates. Moreover, three is no significant reduction in compressive strength with 30% replacement of recycled coarse aggregates. As a result, Kwan et al. (2011) conducted that the optimum level of mix proportion for the replacement of recycled coarse aggregates would be 30%.

3. The Properties of Crumbed Rubberised Concrete

The short lifetime of tyres lead to a waste of rubber, therefore, rubberised concrete has been commonly used in recent decades to achieve the increasing requirements of environmental impact. According to the research by Li, Mills, Benn & Ma (2014), the compressive strength of Rubberised Concrete is slightly lower than the conventional concrete. Moreover, the increasing in the percentage of replacement in rubber could lead to a decreasing the compressive strength. The mix studies indicate a 38% decreasing in compressive strength for RC with 18% replacement of rubber, a 27% decreasing in compressive strength for RC with 15% replacement of rubber. However, the compressive strength of RC with 18% replacement of rubber could still achieve 32MPa which is suitable for most of the structural design. The abrasion resistance could be improved by 160%, 183%, 225% and 333% with 9%, 12%, 15% and 18% replacement of rubber. Moreover, Khaloo, Dehestani & Rahmatabadi (2008) indicate that the increasing in percentage for the replacement of rubber could lead to a large reduction in ultimate strength and the tangential modulus of elasticity. Furthermore, Khaloo, Dehestani & Rahmatabadi (2008) conducted that more than 25% replacement of rubber is not recommended due to a consideration of the decreasing in ultimate strength. Khatib & Bayomy (1999) has also suggested that the rubber content should not exceed 20% of the fine aggregate volume due to the reduction in strength from a practical viewpoint.

4. Early Drop-weight impact test

The drop-weight machine is commonly used for testing on sustainable crumbed rubber concrete in the past several decades. The earlier impact resistance testing on sustainable crumbed rubber concrete was done the UK in 1996 by Fattuhi and Clark (1996).

After the test specimens were prepared, a 30kg drop hammer rig was used to perform the impact test. Admittedly, the drop height of the hammer was set up as 3.0 meters. Moreover, a compression testing machine has been used to determine the maximum compressive loads for each test specimens. It was found that the compressive strength and density of miscellaneous mixes reduced while more rubbers were added, which has shown in table 2 below. Fattuhi and Clark (1996) conducted that the rubber might act as voids which carry a negligible load, and it leads to the decrease in strength.

Furthermore, the result indicates that wider crack might be expected for the rubberized concrete slab (Fattuhi & Clark 1996). However, future studies could be done regarding this research, for example, this experimental research does not have rubber size and rubber pre-treatment conditions in the experimental parameters.

5. Drop-weight impact test for crumb rubberized concrete with estimation of energy absorbed.

According to the research by Sallam et al. (2008), repeated drop-weight test is one of the simplest ways for examining the impact resistance. It could find the number of blows that cause a crack in the test specimen. Meanwhile, the number presents a qualitative estimate of energy absorbed by the test specimen. Repeated drop-weight impact test was done with three different percentage of crumbed rubber replacing of fine aggregate (10%, 20%, and 30%)It was found that the compressive strength of concrete and tensile strength have decreased due to the replacement of sand by crumb rubber. Furthermore, the test results indicate that the failure mode of plain concrete with additional silica fume was more obvious than the failure mode of rubberized concrete with same additional silica fume. (Sallam et al. 2008). To sum up, a more detailed result could be provided by drop weight test combined with estimation of energy absorbed by the material.

6. Drop-weight impact test for recycled aggregate concrete.

Chakradhara Rao, Bhattacharyya and Barai (2011) conducted an experiment for the behavior of recycled aggregated concrete (RAC) by using drop-weight impact test.. Firstly, four RAC mixes were carefully prepared, these four concrete mixes contain 0%, 25%, 50% and 100% recycled aggregates respectively. The drop-weight impact machine has a steel hammer of 50 mm diameter and the mass of the hammer is 5kg, and this hammer is set to drop from 0.225meter height above the test specimens (Chakradhara Rao, Bhattacharyya & Barai 2011). The experimental results indicated that the both tensile and compressive strength of recycled aggregates concrete decrease with the increasing of recycled coarse aggregate content. Moreover, it was found that 100% RCA have a much higher tensile and compressive strain than conventional concrete. However, the influence on strains for 25% RCA is much lower with the drop weight test. Furthermore, the impact resistance decreases with the increasing in the percentages of recycle coarse aggregates (Chakradhara Rao, Bhattacharyya & Barai 2011). In conclusion, drop weight test has also been used to define the impact resistance recycled aggregate concrete.

7. Literature Reviews Summary

To sum up, crumb rubberized concrete has higher impact and abrasion resistance than traditional concrete (Khalil, Abd-Elmohsen & Anwar 2015). However, most of the research indicated that the compressive strength of crumb rubberized concrete decreases with replacing of rubber (Al-Tayeb et al., 2013, Sallam et al. 2008, Khalil, Abd-Elmohsen & Anwar 2015, etc). Moreover, replacement of rubber for aggregate or cement causes the reduction in the flexural strength for both grades (Ganjian, Khorami & Maghsoudi 2009). Drop weight impact test has been used for testing impact resistance for rubber concrete since 1996(Fattuhi & Clark 1996). The impact test is keeping modifying in recent decades, energy absorbed by specimens have also been taken into consideration. The drop-weight impact test also found the compressive and tensile strength of recycled aggregate concrete decreases with the increasing in recycled coarse aggregate content. In addition, the impact resistance of recycled aggregate concrete reduced while the percentage of recycled coarse aggregate increased (Chakradhara Rao, Bhattacharyya & Barai 2011). Furthermore, finite element method is used to simulate the rubberized concrete subject to the impact resistance (Al-Tayeb et al., 2013). Although varieties of research regarding impact resistance of crumb rubberized concrete and recycled coarse concrete were done, the research for the impact resistance of crumb rubberized concrete with recycled coarse

aggregates is limited. As a whole, a research on impact resistance of crumb rubberized concrete with recycled coarse aggregates is highly recommended. Therefore, the following results have been summarised to support the research on impact resistance of crumb rubberized concrete with recycled coarse aggregates.

1. To achieve an acceptable compressive strength, the percentage for the replacement of recycled aggregates could reach 80% with the DoE (Department of Environment in the UK) mix design. There is no significant reduction in compressive strength with 30% replacement of recycled coarse aggregates. A "Sudden Drop" on compressive strength could occur while the percentage for the replacement of recycled aggregates is higher than 30%.

2. The density of the recycled aggregates is less than natural aggregates, and the water absorption of recycled aggregates is higher than natural aggregates.

3. The percentage of volume for the replacement of rubber is recommended to be less than 20% due to a consideration of the decreasing in ultimate strength.

4. 25% RCA does not have much reduction in compressive strength, and it was found the improvement in compressive strength from 28 days to 90 days is not significant. A longer term test is recommended for the future study.

5. The impact resistance of RAC reduces with the increasing percentage of RCA. However, the impact resistance of RC increases with the increasing percentage for the replacement of rubber while the replacement is less than 10%.

6. The workability of RC is higher than conventional concrete, however, the value of slump does not increase with the increasing percentage for the replacement of rubber. 10% extra water need to be added to achieve the same slump value for RAC.

References

[1] Al-Tayeb, M., Abu Bakar, B., Ismail, H. and Akil, H. (2013). Effect of partial replacement of sand by recycled fine crumb rubber on the performance of hybrid rubberized-normal concrete under impact load: experiment and simulation. Journal of Cleaner Production, 59, pp.284-289.

[2] Aiello, M & Leuzzi, F 2010, "Waste tyre rubberized concrete: Properties at fresh and hardened state", Waste Management, vol. 30, no. 8-9, pp. 1696-1704.

[3] Aslani, F 2016, "Mechanical Properties of Waste Tire Rubber Concrete", Journal of Materials in Civil Engineering, vol. 28, no. 3, p. 152.

[4] Chakradhara Rao, M, Bhattacharyya, S & Barai, S 2011, "Behaviour of recycled aggregate concrete under drop weight impact load", Construction and Building Materials, vol. 25, no. 1, pp. 69-80.

[5] Eldin, N & Senouci, A 1994, "Measurement and prediction of the strength of rubberized concrete", Cement and Concrete Composites, vol. 16, no. 4, pp. 287-298.

[6] Fattuhi, N & Clark, L 1996, "Cement-based materials containing shredded scrap truck tyre rubber", Construction and Building Materials, vol. 10, no. 4, pp. 229-236.

[7] Freedonia, 2015, World Tires Market - market research report 2016, Reportlinker, viewed 17 October 2016, <http://www.reportlinker.com/p01972782-summary/World-Tires.html>.

[8] Etxeberria, M, Vázquez, E, Marí, A & Barra, M 2007, "Influence of amount of recycled coarse aggregates and production process on properties of recycled aggregate concrete", Cement and Concrete Research, vol. 37, no. 5, pp. 735-742.

[9] Ganjian, E, Khorami, M & Maghsoudi, A 2009, "Scrap-tyre-rubber replacement for aggregate and filler in concrete", Construction and Building Materials, vol. 23, no. 5, pp. 1828-1836.

[10] Jacob, P, Kashyap, P, Suparat, T & Visvanathan, C 2014, "Dealing with emerging waste streams: Used tyre assessment in Thailand using material flow analysis", Waste Management & Research, vol. 32, no. 9, pp. 918-926.

[11] Khaloo, A, Dehestani, M & Rahmatabadi, P 2008, "Mechanical properties of concrete containing a high volume of tire–rubber particles", Waste Management, vol. 28, no. 12, pp. 2472-2482.
[12] Khatib, Z & Bayomy, F 1999, "Rubberized Portland Cement Concrete", Journal of Materials in Civil Engineering, vol. 11, no. 3, pp. 206-213.
[13] Kwan, W, Ramli, M, Kam, K & Sulieman, M 2011, "Influence of the amount of recycled coarse aggregate in concrete design and durability properties", Construction and Building Materials, vol. 26, no. 1, pp. 563-573.
[14] Khalil, E, Abd-Elmohsen, M & Anwar, A 2015, "Impact Resistance of Rubberized Self-Compacting Concrete", Water Science, vol. 29, no. 1, pp. 45-53.
[15] Li, D, Mills, JE, Benn, BT and Ma, X 2014. "Abrasion and impact resistance investigation of crumbed rubber concrete (CRC)", Construction and Building Materials, vol. 124, pp. 906-909.
[16] Liu, F, Chen, G, Li, L & Guo, Y 2012, "Study of impact performance of rubber reinforced concrete", Construction and Building Materials, vol. 36, pp. 604-616.
[17] Liu, F, Zheng, W, Li, L, Feng, W & Ning, G 2013, "Mechanical and fatigue performance of rubber concrete", Construction and Building Materials, vol. 47, pp. 711-719.
[18] Naito, C, States, J, Jackson, C & Bewick, B 2014, "Assessment of Crumb Rubber Concrete for Flexural Structural Members", Journal of Materials in Civil Engineering, vol. 26, no. 10, p.75.
[19] National Physical Laboratory. (2010). FEA Software (Abaqus, Ansys, Pafec, LUSAS, Moldflow, Comsol), viewed 17 October 2016, <http://www. npl.co.uk/ science- technology /advanced -materials /materials-areas/thermodynamics/fea-software>.
[20] Rahal, K 2007, "Mechanical properties of concrete with recycled coarse aggregate", Building and Environment, vol. 42, no. 1, pp. 407-415.
[21] Sallam, HEM, Sherbini, AS, Seleem, MH. and Balaha, MM, 2008, Impact resistance of rubberized concrete, Engineering Research Journal, vol. 31, pp.265-271.
[22] SANS from MTS China 2016, Drop weight impact tester, viewed 10 October 2016, <http://www.sans.cn/product/list.asp?ClassId=112>.
[23] Siddique, R & Naik, T 2004, "Properties of concrete containing scrap-tire rubber – an overview", Waste Management, vol. 24, no. 6, pp. 563-569.
[24] Youssf, O, ElGawady, M, Mills, J & Ma, X 2014, "Prediction of crumb rubber concrete strength", Construction and Building Materials, vol. 53, pp. 522-532.