View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Digital Commons @ BAU (Beirut Arab University)

BAU Journal - Science and Technology

Volume 1 | Issue 1
ISSN: 2706-784X

Article 4

December 2019

A REVIEW ON THE USE OF VEGETABLE OIL AND ITS WASTE IN CONSTRUCTION APPLICATIONS

Ahmed Chamaa
Student, Faculty of Engineering, Beirut Arab University, Beirut, Lebanon, asel182@student.bau.edu.lb

Jamal Khatib
Professor, Faculty of Engineering, Beirut Arab University, Beirut, Lebanon, j.khatib@bau.edu.lb

Adel Elkordi
Faculty Dean Professor, Faculty of Engineering, Beirut Arab University, Beirut, Lebanon, a.elkordi@bau.edu.lb

Follow this and additional works at: https://digitalcommons.bau.edu.lb/stjournal

Part of the Architecture Commons, Business Commons, Engineering Commons, and the Physical Sciences and Mathematics Commons

Recommended Citation

Chamaa, Ahmed; Khatib, Jamal; and Elkordi, Adel (2019) "A REVIEW ON THE USE OF VEGETABLE OIL AND ITS WASTE IN CONSTRUCTION APPLICATIONS," *BAU Journal - Science and Technology*: Vol. 1 : Iss. 1 , Article 4.
Available at: https://digitalcommons.bau.edu.lb/stjournal/vol1/iss1/4

This Article is brought to you for free and open access by Digital Commons @ BAU. It has been accepted for inclusion in BAU Journal - Science and Technology by an authorized editor of Digital Commons @ BAU. For more information, please contact ibtihal@bau.edu.lb.

A REVIEW ON THE USE OF VEGETABLE OIL AND ITS WASTE IN CONSTRUCTION APPLICATIONS

Abstract

The generation of waste materials is causing an impact on the environment due to many reasons including the effect on human health and decrease in landfill space. Of these waste materials is the waste cooking oil. There are large amounts of waste vegetable oil generated in the world and most of it is disposed of in the sewer system which can cause problems when treating wastewater. This paper is a review of literature on the use of vegetable oil (VO) and waste vegetable oil (WVO) as chemical admixtures in construction materials. The construction materials include mainly concrete and pavement. The properties examined were fresh, mechanical and durability properties. Fresh properties included slump test while the mechanical properties comprised compressive and flexural strength as well as shrinkage. The durability and durability related properties consisted of water absorption both by total immersion and capillary action, carbonation and efflorescence. This review suggests that virgin vegetable oil and its waste has the potential to be used as chemical admixtures in construction materials to improve their workability water resistance.

Keywords

Bio-based material, concrete, pavement, sustainable construction, waste vegetable oil.

This article is available in BAU Journal - Science and Technology: https://digitalcommons.bau.edu.lb/stjournal/vol1/iss1/4

1. INTRODUCTION

The global climate is threatened by ongoing increase in pollution. Every year, there are an increase in the amount of waste in the world, such as waste oil products. One of the most consumed oil is the vegetable oil used for cooking.

There are large amounts of waste vegetable oil produced globally. Up to 1 million and 0.6 million tons of WVO per year are generated in the European Union and Japan respectively (Chhetri et al., 2008, Ganesh et al., 2013). China, the world loader, generates about 4.5 million tons of waste vegetable oil (Ganesh et al., 2008). This huge amount of WVO produced annually requires adequate provision for its collection and disposal.

The negative impact of disposing waste oil should be reduced. In the European Union (EU) countries and Turkey, for example, the disposal of waste oil in the wastewater systems, moving or stagnant water is prohibited. There is less waste oil contamination the EU countries compared with other countries in the world, because actions started earlier. Many countries in the world will follow the same actions taken by the EU.

There are stringent requirements and rules regarding the disposal of waste oil in general including waste vegetable oil. Biodiesel and consequently electricity can be produced from waste vegetable oil and many companies are reusing and processing WVO for that purpose. There was about 1.9 million L of biodiesel per year produced for WVO (Greer, 2013). The calorific value of WVO was found to two and half time that of virgin oil. This shows that WVO can be a good source of energy and can be used for the production of hydrogen gas and pyrolytic oil as well as the generation of electricity (Khalisanni et al., 2008). The aim of this paper is to review the incorporation of vegetable and waste vegetable oil in construction materials such as mortar, concrete, bricks, building blocks and asphalt mixtures. The review covers the various properties of construction materials containing cooking vegetable oil and waste vegetable oil. These included, fresh properties, mechanical properties and durability properties. It is expected that this review will form the basics of further research on the use of WVO.

2. SLUMP

Beddu et al. (2015) reported the effect of adding WVO on the workability of concrete. They found that there is negligible difference in slump when adding 0.25% of WVO. Beyond 0.25% addition, the slump began to increase. An increase in slump of 4% was obtained at 0.5% addition and the increase was substantial at 2% where the slump was twice that of the control. The presence of WVO may have the role of a water reducing admixture (Beddu et al., 2015). The results are shown in Figure 1. Similar results are reported elsewhere (Salmia et al., 2013, Bhairavi and Mallikarjuna, 2018).

However, other researchers found a reduction in slump was obtained in the presence of WVO (Chandrasekar et al., 2016, Han et al., 2014).

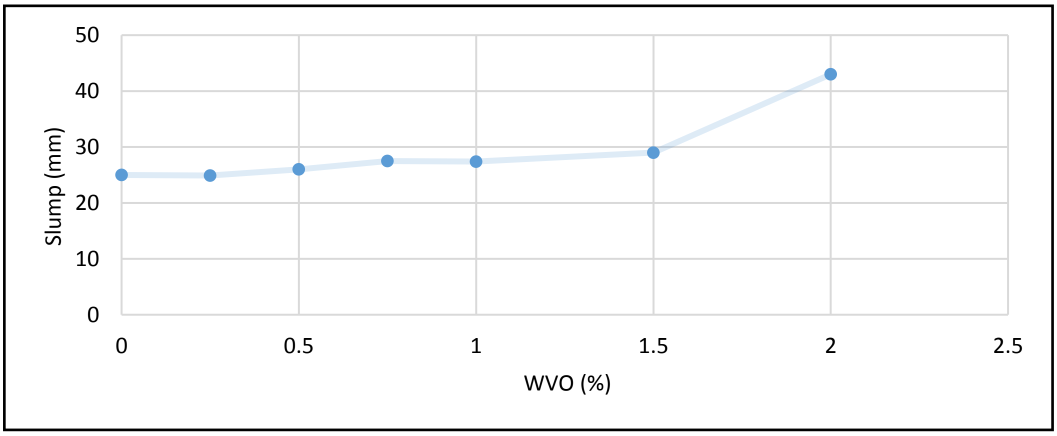

Fig.1: Slump of concrete containing waste vegetable oil (Beddu et al., 2015).

3. COMPRESSIVE STRENGTH

Justnes et al. (2004) studied the effect of adding different types of vegetable oil on the properties of mortar. The dosages of oil varied from 0 to 1.5% by weight of cement. They found that there is an improvement in workability, resistance to water penetration and slight reduction in compressive strength. Similar results were reported elsewhere (Chandra and Xu., 1995, Rahman et al., 2016). However, other researchers found a slight increase in compressive strength when vegetable oil was used in concrete (Beddu et al., 2015, Salmia et al., 2013). The variation in the results may attributed to the dispersion agent used in each case. However, the compressive strength beyond 14 days of curing increased at 1.5% addition and decreased at 1 and 2% addition of waste cooking oil (Chandrasekar et al., 2016). There was a slight change in compressive strength during the early ages of curing. Table 1 summarizes the results obtained.

Table 1: Compressive strength for M20 grade concrete containing vegetable oil (VO) (Chandrasekar et al., 2016).

VO (%)	Compressive strength(N/mm^2)			
	3 days	7 days	14 days	28 days
0 (control)	5.02	9.5	13.48	20.97
1	5.65	9.04	11.08	16.63
1.5	6.55	9.06	14.95	21.53
2	6.27	8.88	11.34	17.96

The incorporating WVO in the production of building blocks at high temperatures was examined (Adebayo et al., 2018). The temperature varied from 160 to 200°C. There was a drastic decrease in strength at 200°C of exposure and the best performance was observed when the block were exposed to 170°C. The summary of all properties examined including strength, energy absorbed and porosity is reported in Table 2.

Table 2: Properties of building block exposed to different temperatures (Adebayo et al., 2018)

	Temperature (°C)				
	160	170	180	190	200
Compressive strength (MPa)	29.0	34.3	23.0	23.0	5.7
Stiffness (MPa)	1969	2015.75	1108.83	549.5	263
Energy absorbed (J/m^3)	1337	1925	1109	955	946
Porosity (%)	11.5	13.0	12.6	12.7	17.7

Adding WVO to Self-Compacting Concrete (SCC) was found to cause strength enhancement by 5.25%, 6.45%, 15.04% and 24.3% for mixes containing 0.25%, 0.5%, 1% and 1.5% of used cooking oil respectively (Bihairavi and Mallikarjuna., 2018). The optimum was obtained at 1.5% of WVO. Table 3 summarize the results obtained.

Table 3: Compressive strength for self- compacting concrete containing waste vegetable oil. (Bhairavi and Mallikarjuna, 2018)

Oil (%)	Compressive strength (MPa) at:		
	3 days	7 days	28 days
0 (Control)	17.5	20.0	29.1
0.25	18.2	21.1	30.7
0.5	19.6	21.8	31.0
1	20.6	22.3	33.5
1.5	21.0	23.6	35.3

Han et al. (2014) studied the incorporation of emulsified refined cooking oil (ERCO) in concrete containing high volume of fly ash and blast furnace slag. Up to 2% of ERCO (by mass of binder) was added to the concrete. Concrete containing 30% of fly ash and 60% of blast furnace slag. They showed that until 56 days, ordinary Portland cement exhibited the highest strength compared to the other mixes regardless of the % addition of ERCO. The presence of ERCO was found to reduce the compressive strength. This loss in strength can be explained by the fact that the fat component of ERCO inhibits the hydration of cement. Yaacub et al. (2013) examined the influence virgin and waste vegetable oil on the compressive strength of bricks. The dosages of oil were 5%, 7%, 9%, 11%, and 13% by weight of the brick. Specimens were heated at 160°C for 24, 48 and 72 hours. The highest compressive strength was found for brick containing 11% vegetable oil and cured for 72hours. However, the lowest strength was found for those containing 13% oil and cured at 24 hours. The results are presented in Figure 2 and Figure 3 for bricks with virgin oil and waste vegetable oil respectively.

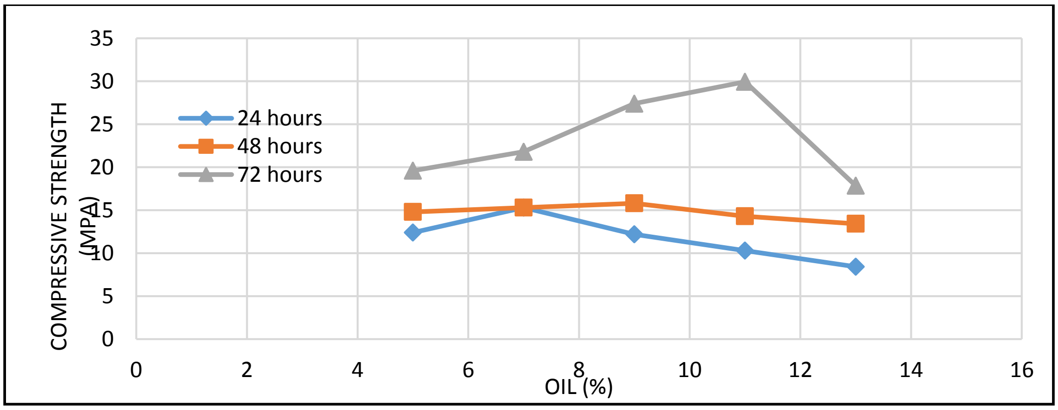

Fig.2: Compressive strength for bricks with virgin oil (Yaacub, September 2013).

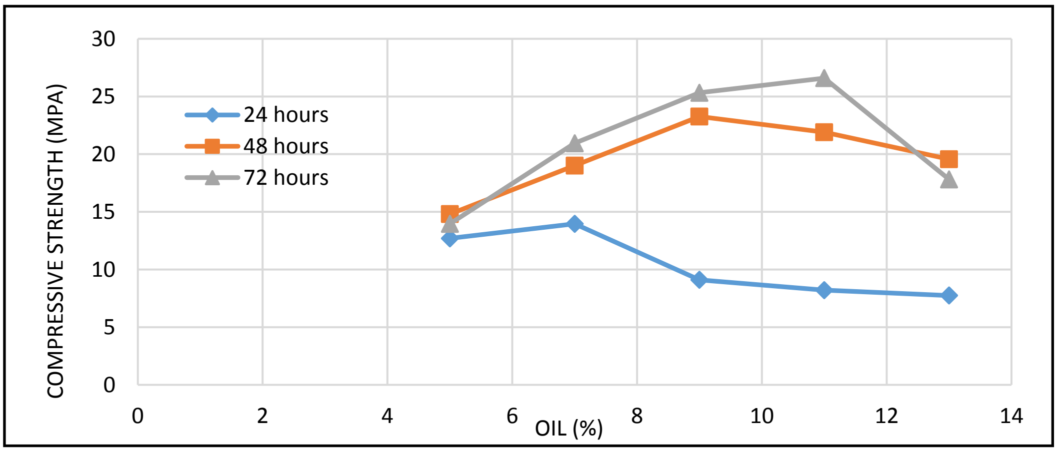

Fig.3: Compressive strength for bricks with WVO (Yaacub, September 2013).

Masonry units were produced using incinerator bottom ash (IBA), pulverized fuel ash (PFA) (Vu et al., 2017). Glycerol and cooking oil were added to these units. The curing temperature of the masonry units was 160°C for different durations.

The compressive strength of the units was found to increase from 24 to 32 MPa when the curing duration increased from 24 to 96 hours respectively. In other investigations, it was found that either bitumen (Forth et al., 2004, Forth et al., 2006, Forth et al., 2010a, Forth et al., 2010b, Vu et al., 2014) or WVO (Forth and Zoorob, 2006, Zoorob et al., 2006, Heaton et al., 2012) can be used in the production of masonry units.

4. FLEXURAL STRENGTH

Justnes et al. (2004) studied the utilization of different types of vegetable oil in mortar mixes. They showed that generally at 1 day of curing there was only a slight reduction in flexural strength in the presence of vegetable oils. The mix which exhibited large reduction (20%) in flexural strength contained 1% corn oil. At longer period of hydration (i.e. 28 days), the reduction in strength was between 15% and 23%. The presence of oil does not seem to inhibit the degree of hydration. Beddu et al. (2015) showed that the flexural strength increased by 11.7% when adding 1.5% of used vegetable oil. However, there was a decrease by 6% when 2% of WVO was added. The flexural strength data are summarized in Figure 4.

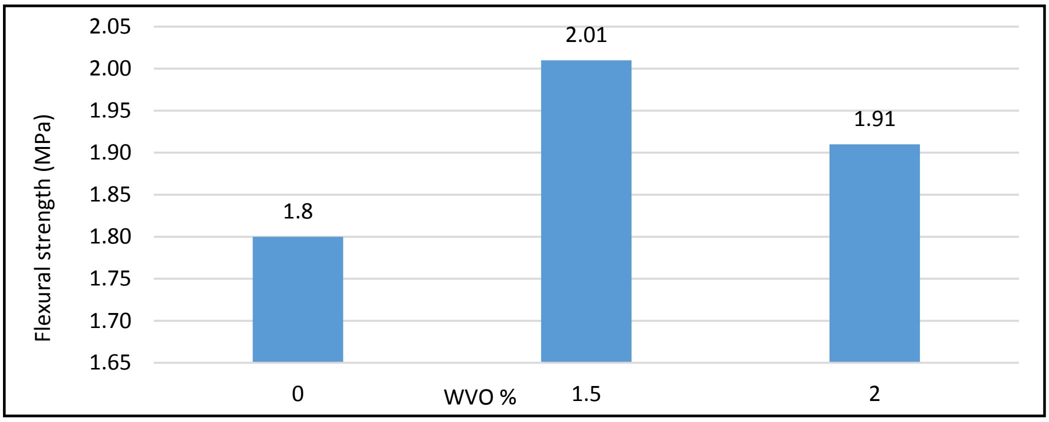

Fig.4: Flexural strength for concrete containing waste vegetable oil (WVO) (Beddu et al., 2015).

It is observed that the flexural strength of self-compacting concrete increased after addition of waste vegetable oil (WVO). The optimum was obtained at 1.5% of WVO (Bhairavi and Mallikarjuna, 2018).The optimum was obtained at 1.5% of WVO. The results on flexural strength are presented in Table 4.

Table 4: Flexural strength of concrete containing waste vegetable oil (Bhairavi and Mallikarjuna, 2018)

WVO* (%)	Compressive strength (MPa) at:		
	3 days	7 days	28 days
0 (Control)	2.9	3.1	3.8
0.25	3.0	3.2	3.9
0.5	3.1	3.3	3.9
1	3.2	3.3	4.1
1.5	3.2	3.4	4.2

*Waste vegetable oil (% by weight of cement)

5. SPLIT TENSILE STRENGTH

The Split tensile strength of concrete was found to increase by 5.25, 30.5, 25.35 and 30.5% with adding 0.25, 0.5,1 and 1.5% of used cooking oil respectively (Bhairavi and Mallikarjuna, 2018). Two optimum was obtained at 0.5 and 1.5% WVO. TABLE 5 gives details on the split tensile strength for the various concrete mixes.

Table 5: Split tensile strength of concrete containing waste vegetable oil (Bhairavi and Mallikarjuna, 2018)

WVO* (%)	Split tensile strength (MPa) at:		
	3 days	7 days	28 days
0 (Control)	1.8	2.25	2.912

0.25	1.8	2.3	3.1
0.5	2.3	2.8	3.8
1	2.5	2.6	3.7
1.5	2.6	3.0	3.8

6. DENSITY

There seems to be an enhancement in the concrete density in the presence of sunflower oil (Rahman et al., 2016). The higher the content of oil, the higher the density. There is only one exception at 0.5% sunflower oil where was a noticeable increase in density compared to the other mixes. Figure 5 shows all the results obtained.

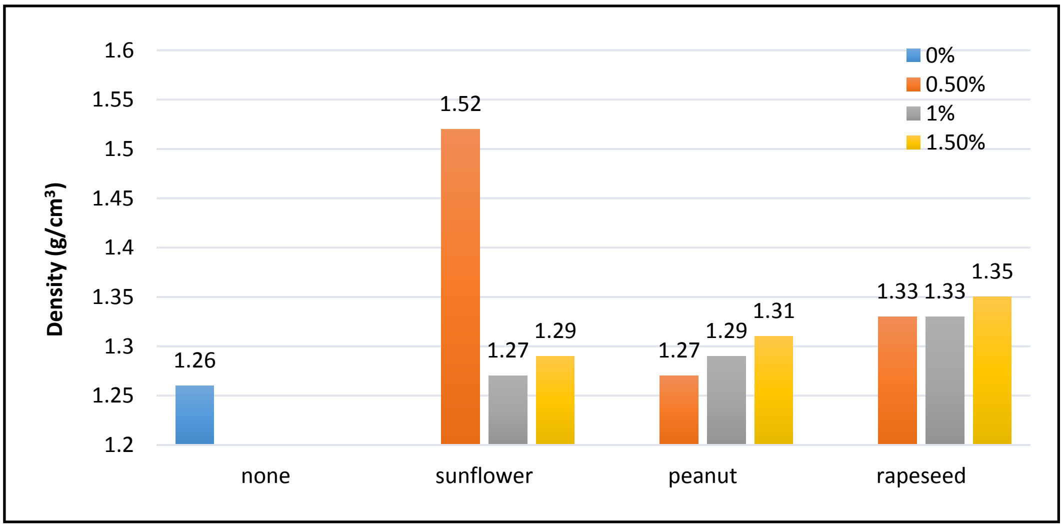

Fig. 5: Density of concrete containing different types of vegetable oil (Rahman et al., December 2016).

The density of bricks containing cooking oil was found to increase regardless of the curing age (Yaacub, 2013). This increase can be as high as 13%. There is a decrease in bulk density for masonry block containing glycerol and cooking oil (Vu et al., 2017). The bulk density was found to range between 1.64g/cm^3 and 1.83g/cm^3 which is lower than the control mix (1.91g/cm^3). The incorporation of incineration bottom ash aggregate was found to further decrease the bulk density.

7. EFFLORESCENCE

Adebayo et al. (2018) examined the efflorescence of building blocks containing waste vegetable oil. Some blocks were partially immersed in water and some were placed in a dry room for 7 days. The blocks were then dried in an oven for 24 hours. The sides of all blocks were carefully examined after drying. It was noticed that regardless of the exposure method, the blocks did not show any sign of efflorescence.

8. HEAT OF HYDRATION

Chandrasekar et al. (2016) monitored the surface temperature of conventional concrete cubes (cured in pure water) and water containing vegetable and fruit peel extracts). At the end of 3, 7, 14 and 28 days of curing period, it was found the surface temperature of cubes cured in water was 3 to 4 °C higher than those cured in water containing vegetable oil and fruit extract. The surface temperature of cubes is presented in Table 6.

Table 6: Surface temperature of cubes cured in two different medium
(Chandrasekar et al., 2016)

Age of curing (days)	Average surface temperature of concrete cubes (°C) cured in:	
	Pure water	Water containing WVO and vegetable extract

3	29.6	27.8
7	32.4	30.2
14	32.6	29.6
28	33.2	30.1

9. MERCURY INTRUSION POROSIMETRY

Han et al. (2014) evaluated the porosity and pore size distribution at 28 days of concrete with and without emulsified refined cooking oil (ERCO). They observed that the pore size and the pore volume inside concrete decreases as ERCO dosage increases. This is explained by the reaction between the oil and hydration products that fill the pores (Han et al., 2014).

10. WETTING/DRYING RESISTANCE

Adebayo et al. (2018) investigated the resistance of masonry blocks containing waste oil to repeated wetting and drying cycles. Blocks were exposed to ten cycles of wetting and drying. Each cycle consists of five hours of immersion in water followed by forty-two hours in an oven at 71°C. Figure 6 shows the mass loss after each cycle. However, there was no sign of deterioration after the wetting and drying exposure test.

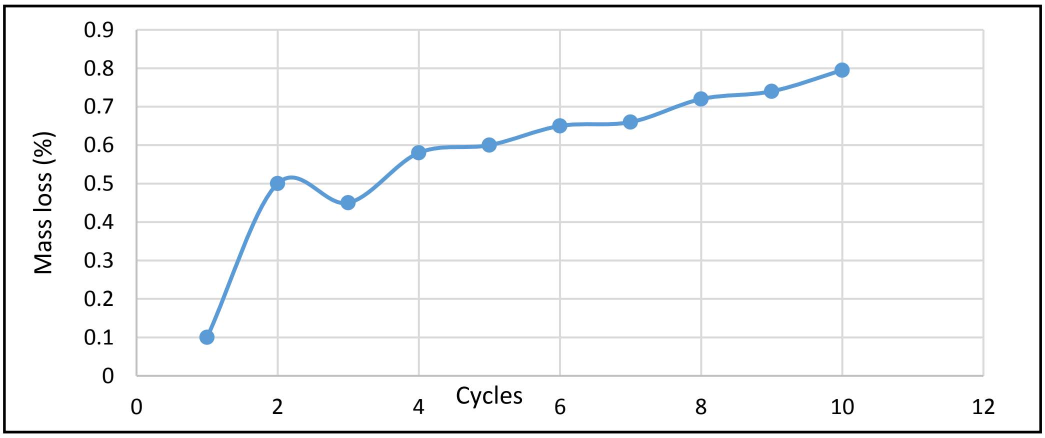

Fig.6: Mass loss for masonry blocks during the wetting–drying cycles(Adebayo et al., 2018).

11. CARBONATION

Han et al. (2014) found that by adding emulsified refined cooking oil (ERCO) to the concrete mix, the carbonation depth increase with the age of curing. However, the presence of ERCO caused a reduction in carbonation. This was justified by the filling of the capillary pores inside the hardened concrete.

12. WATER ABSORPTION

Adding vegetable oil to concrete was found to have a market decrease on water absorption (by capillary suction) (Justnes et al., 2004). Rahman et al. (2016) reported similar results on water absorption by total immersion of mortars. Mortars with and without vegetable oil were cured for 25 days. The water absorption tests after 48h immersion in water at a temperature of 27 ± 2°C and boiling at a temperature of 100°C for 24h. Generally, more than 60% reduction in water absorption was observed in some mortar mixes in the presence of oil. The results are reported in Figure 7 and Figure 8.

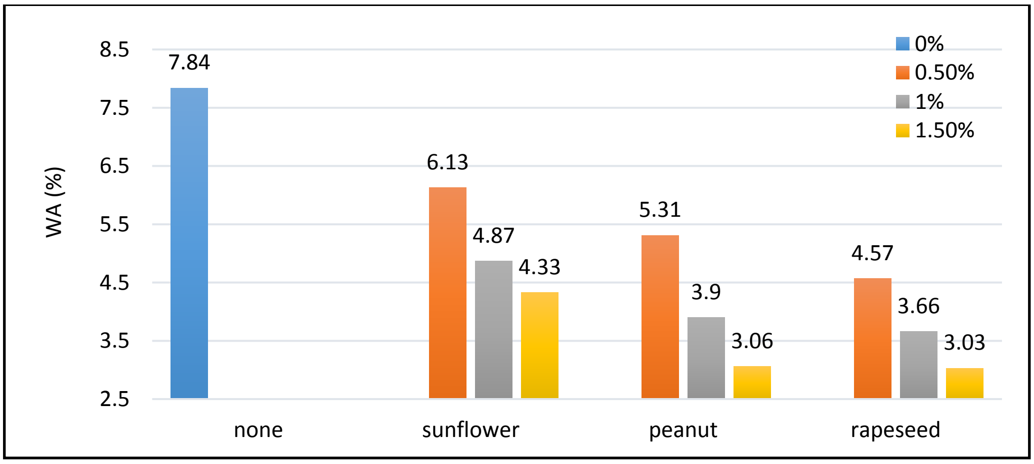

Fig.7: Water absorption of mortar specimens containing vegetable oil immersed in water at 27°C for 48 hours (Rahman et al., 2016).

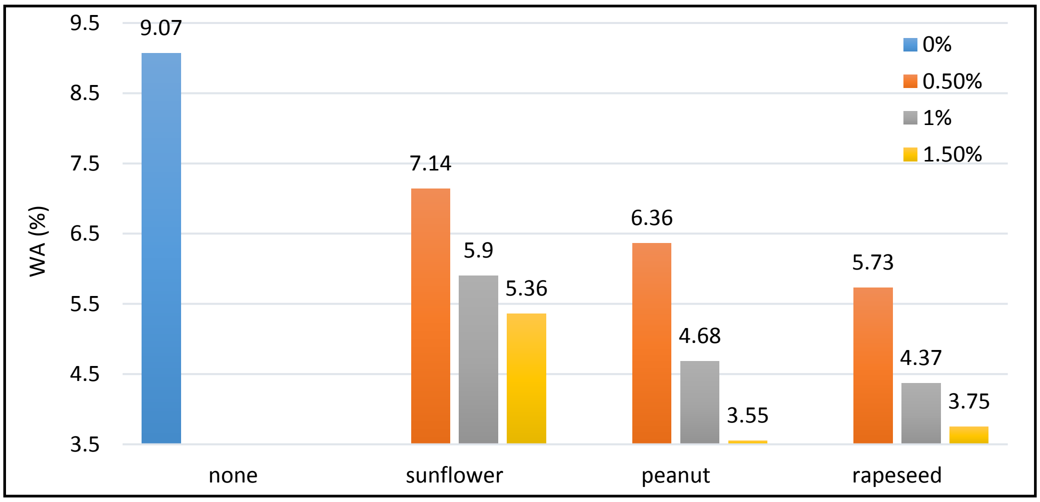

Fig.8: Water absorption of mortar specimens containing vegetable oil immersed in water at 100°C for 24 hours (Rahman et al., 2016).

The reduction in water absorption in the presence of vegetable oil was found to decrease in bricks and masonry block (Adebayo et al., 2018, Yaacub, 2013, Vu et al., 2017). The results are shown in Figure 9. Based on the results shown in Figure 9, there is an increase in water absorption as the immersion time increases up to at least 7 days. The lowest water absorption was observed for the control specimens compared with those containing pure binder or waste binder.

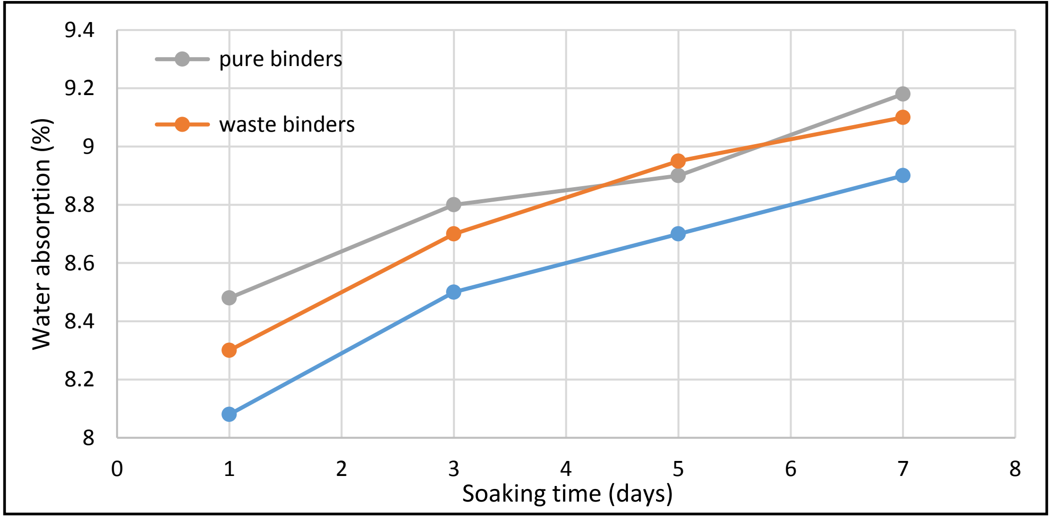

Fig. 9: Water absorption for concrete with pure binders, waste binders and natural aggregates (Vu et al., 2017).

13. ASPHALT MIXTURES

Mathur et al. (2018) investigated the effect of waste vegetable oil (WVO) on the properties of hot reclaimed asphalt mixture. They showed that the performance of the mixture improves when incorporating waste cooking oil. They showed also that inclusion of WVO decreases the indirect tensile strength, increase the strain at failure and decrease the resilient modulus and the rutting resistance of asphalt mixtures. However, the dissipated creep strain energy was found to decrease. The decrease in rutting resistance is in agreement with results reported elsewhere (Majidifard et al., 2019).

Majdifard et al. (2019) investigated the influence of incorporating WVO on the performance of high reclaimed asphalt mixtures. They showed that using WVO reduced the stiffness and increased the m–value of the mixture. Also adding WVO improves the mixture workability and reduces the moisture and rutting resistance. This improved behaviour is in agreement with results reported elsewhere (Buttlar et al., 2019, Al-Omari et al., 2018, Zaumaris et al., 2013, Mirhosseini et al., 2018, Asli et al., 2012, Chen et al., 2014, Gong et al., 2016, Dokandari et al., 2017, Zhou et al., 2019).

14. CONCLUSIONS

Based on the review of the literature, it can be concluded that:

A. Using Vegetable and waste vegetable oil can be used as water repellents for mortars and concrete in small amounts (e.g. 0.5%-1.5% by weight of cement). The carbonation depth in concrete is reduced in the presence of vegetable oil. The workability, split tensile strength and flexural strength can increase in the presence of vegetable oil.

B. Waste Vegetable oil can be incorporated in the production of masonry block in order to reduce water ingress.

C. The incorporation of vegetable oil in asphalt mixtures leads to a decrease in the indirect tensile strength, increase the strain at failure and decrease the resilient modulus and rutting resistance.

REFERENCES

- Adebayo, J. O., Napiah, M., Ibrahim, K., & Kabit, M. R. (2018). Evaluation of Waste Cooking Oil as Sustainable Binder for Building Blocks. In *E3S Web of Conferences* (Vol. 65, p. 05003). EDP Sciences.
- Al-Omari, A. A., S. Taisir, Khedaywi, S., and M. A. Khasawneh, M. A. (2018). Laboratory Characterization of Asphalt Binders Modified With Waste Vegetable Oil Using Superpave Specification. *International Journal of Pavement Research and Technology*, 11, 68- 76.
- Asli, H., Ahmadinia, E., Zargar, M., Karim, M., 2012. Investigation on Physical Properties of Waste Cooking Oil Rejuvenated Bitumen Binder. *Construction and Building Materials*, 37, 398-405.
- Beddu, S., Talib, S.H.A., Kamal, N.L.M., Zakaria, C.M., Yap, K.W and Khizdir, A.B.M. (2015).The Performance of Concrete Containing Used Cooking Oil. *Proc. of the third Intl. conf. on advances in civil and structural engineering-CSE*, 65-70.
- Bhairavi, A.S. and Mallikarjuna, R. (2018). Effect of Used Cooking Oil on Mechanical Properties of Self -Compacting Concrete in M20 Grade. *International Journal of Research in Advent Technology (IJRAT) special, E- ISSN: 2321-9637*, 143-147.
- Buttlar, W., Rath, P., Majidifard, H., Dave, E. V., & Wang, H. (2018). Relating DC (T) Fracture Energy to Field Cracking Observations and Recommended Specification Thresholds for Performance-Engineered Mix Design. *Asphalt Mixtures*, 51-71.
- Chandra, S., & Xu, A. (1995). Influence of Vegetable Oils Addition on Portland Cement Mortars. In *7th International Congress on Polymers in Concrete (ICPIC), Oostende* (Vol. 35), 187-192.
- Chandrasekar, M., Karthikeyan, S. K., Snekha, G., Vinhotini, A. (2016). Experimental Investigation on Usage of Waste Vegetable Oil (WVO) in Concrete Making and Adopting Innovative Curing Method. *International Journal of Engineering Research Technology (IJERT)*, 5(4), 146-151.

- Chen, M., Leng, B., Wu, S., & Sang, Y. (2014). Physical, Chemical and Rheological Properties of Waste Edible Vegetable Oil Rejuvenated Asphalt Binders. *Construction and Building materials*, *66*, 286-298.
- Chhetri, A. B., Watts, K. C. and Islam, M. R. (2008). Waste Cooking Oil as an Alternate Feedstock for Biodiesel Production, *Energies* 1(1), 3-18.
- Dokandari, P. A., Kaya, D., Sengoz, B., & Topal, A. (2017). Implementing waste oils with reclaimed asphalt pavement. In *Proceedings of the 2nd World Congress on Civil, Structural and Environmental Engineering (CSEE'17)* (pp. 1-12).
- Forth, J. P., & Zoorob, S. E. (2006). Non-Traditional Binders for Construction Materials. In *Proceedings of the IABSE Henderson Colloquium, Cambridge, UK*.
- Forth, J. P., Dao, D. V., Toropov, V. V., & Vu, H. M. (2010). Experimental and Mathematical Optimisation of a Novel Sustainable Masonry Unit. *Masonry International*, *23*(3), 103-111.
- Forth, J. P., Dong, V. D., Toropov, V.V. and Vu, H. M. (2010). Development and Optimization of a Novel Sustainable Masonry Unit. *Masonry International*, 23(3).
- Forth, J. P., Zoorob, S. E., and Thanayai, N. A. (2006). Bitublock - A Novel Construction Unit Composed Entirely Of Recycled and Waste Aggregates. *Proceedings of the Institution of Civil Engineers-Construction Materials*, 159, CMI.
- Forth, J. P., Zoorob, S. E., & Dong, V. D. (2004, November). The Development of a Masonry Unit Composed Entirely Of Recycled And Waste Aggregates. In *International RILEM Conference on the Use of Recycled Materials in Buildings and Structures*.
- Gong, M., Yang, J., Zhang, J., Zhu, H., & Tong, T. (2016). Physical–Chemical Properties of Aged Asphalt Rejuvenated by Bio-Oil Derived From Biodiesel Residue. *Construction and Building Materials*, *105*, 35-45.
- Greer, D. (2013). Recycling Local Waste Oil and Grease into Biodiesel. Retrieved from www.ybiofuels.org

- Han, M. C., Han, C. G., Huang, J. G., and Lee, M. H. (2014). Effect of Emulsified Refined Cooking Oil on the Carbonation Mitigation of High Volume Mineral Admixture Concrete. *The 2014 world congress on Advances in civil Environmental, and materials Research (ACEM14),* 1-8.

- Heaton, T., Fisher, J., & Forth, J. P. (2012). Waste Rapeseed Oil Used as a Binder for Masonry Units: NMR Spectroscopic Analysis. *Journal of the American Oil Chemists' Society*, *89*(6), 1101-1111.

- Justnes, H., Østnor, T. A., & Barnils Vila, N. (2004, October). Vegetable Oils as Water Repellents for Mortars. In *Proceedings of the 1st International Conference of Asian Concrete Federation, Chiang Mai* (pp. 28-29).

- Khalisanni, K., Khalizani, K., Rohani, M. S. and Khalid, P. O. (2008). Analysis of Waste Vegetable Oil as Raw Material for Biofuel Production. *Global Journal of Environmental Research*, 2 (2), 81-83.
- Majidifard, H., Tabatabaee, N.D., and Buttlar. W. (2019). Investigation Short – Term and Long – Term Binder Performance of High – RAP Mixtures Containing Waste Cooking Oil. *Journal of Traffic and Transportation Engineering*, 6(4), 396-406.
- Mathur, S.P., Lata, N., and Nagar, B. (2018). Preparation of BC Mix Using Waste Cooking Oil as Rejuvenator for RAP. *International Journal for Research in Applied Science Engineering Technology (IJRASET*), 6(8), 709-724.
- Mirhosseini, A. F., Kavussi, A., Tahami, S. A., Dessouky, S. (2018). Characterizing Temperature Performance of Bio-Modified Binders Containing RAP Binder. *Journal of Materials in Civil Engineering*, 30(8). 1-11.
- Maddikeri, G. L., Pandit, A. B., & Gogate, P. R. (2012). Intensification Approaches for Biodiesel Synthesis from Waste Cooking Oil: A Review. *Industrial & Engineering Chemistry Research*, *51*(45), 10-28.
- Rahman, Z. D., Jeyamugesh, S., Ilakkiya, N., Vijayaraghavan, J. (2016). Mineral Additive Based Mortar for the Enhancement of Water Repellent Properties. *Engineering & Technology in India,* 1(5), 157-166.

- Salmia, B., Muda, Z. C., Ashraful, M. A., Sidek, L. M., Hidayah. B. (2013). Used Cooking Oils Chemical Admixture in Concrete. *4th International Conference on Energy and Environment*, (16), 1-4.
- Vu, H. M., Forth, J. P., and V. V. Toropov, V. V. (2017). The Use of Glycerol and Cooking Oil in Masonry Unit Production. *Proceedings of the Institution of Civil Engineers-Construction Materials*, 170 (2), 77- 90.
- Vu, H. M., and Forth, J. P. (2014). Mechanisms Strength Development in Masonry Units Using Blended Organic Binders. *Journal of Construction and Building Materials*, 52, 294-305.
- Yaacub. N. B. (2013). Compressive Strength of Brick with Used Cooking Oil. *Civil Engineering Technolog*y Petronas, 1-47.
- Zaumaris, M., R. Mallick, R. and Frank, R. (2013). Evaluation of Rejuvenator s Effectiveness with Conventional Mix Testing for 100% Reclaimed Asphalt Pavement Mixtures. *In Transportation Research Record: Journal of the transportation Research Board, No. 2370*, 17 – 25.
- Zhou, J., Zeng, M., Chen, Y. and Zhong, M. (2019). Evaluation of Cement Stabilized Recycled Concrete Aggregates Treated with Waste Oil and Asphalt Emulsion. *Construction and Building Materials*, 199, 143 – 153.
- Zoorob, S. E. Forth. J. P. and Bailey. H. K. (2006). Vege Block: Masonry Units from Recycled Waste and Vegetable Oil. *21st International Conference on Solid Waste Technology and Management*; Philadelphia, USA.