5th International Conference of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Virtually from Québec City, Canada – May 11-14, 2021

SHRINKAGE BEHAVIOR OF BIO-FIBRE REINFORCED AGRO-CEMENTITIOUS MATERIAL

Diba Ahadzadeh Ghanad[1], Ahmed Soliman[1,3], Stephane Godbout[2],Joahnn Palacios[2]

[1] Concordia University, Montreal, Quebec, Canada, H3G 1M8
[2] Institut de recherche et de développement en agroenvironnement (IRDA), Québec, Canada, G1P 3W8
ahmed.soliman@concordia.ca

CSBE21451 – **Presented at 9th International Symposium on Cement Based Materials for a Sustainable Agriculture (CSA)**

ABSTRACT Bio-based agriculture products had been used in many humans daily used products due to their lightweight, thermal insulation, and positive environmental impact (i.e. carbon-negative). Hence, more attention is given to bio-based products and ways to implement in different applications to achieve sustainability. Among these applications, construction applications represent a promising domain that is eager to such materials to add new functionalities and increase sustainability for various products. This study investigates the potential of using fiber-like agriculture biomass to improve shrinkage cracking resistance and flexural strength for cementitious materials. Fiber-like biomass was added at rates 1%, 3%, and 6% as a partial replacement of natural aggregate by volume. Agriculture fibers bridge cracks and restrain their propagation, hence, increased the tensile strength for cementitious materials. This highlights the potential of using such sustainable fiber instead of regular types in non-structural building materials.

Keywords: shrinkage, Bio-fibre, waste , Concrete, Crack resistance

INTRODUCTION With more than 10 billion tons produced annually, concrete is the most important construction material [1]. It has been predicted that the world’s population will increase to 11 billion by the end of the century, which considerably increases the demand for concrete. It is expected that concrete production will grow to approximately 18 billion tons by 2050 [2]. Concrete is been used in wide range of constructional applications including bridge, roads, tunnels, and various buildings. For farm and livestock buildings, concrete is strong competitor to other building materials due to its strength and durability in such harsh environment. The high resistance of concrete to different aggressive materials generated in pigs, cattle and poultry aggressions make it the basic materials for such structure. Also, the texture of the concrete makes smooth surfaces easy to clean. Concrete walls have a high resistance for fire which will increase safety of various farm buildings. There are many advantages that are associated with the use of concrete in farm buildings.

However, concrete industry is facing major challenges with respect to it ecological and environmental impact. Concrete industry consumes a significant amount of energy, water, aggregate, fillers and other natural resources to produce cement and concrete. Moreover, at the end of its life cycle, construction waste from the demolition of concrete structures is another environmental impact [5,7]. Hence, there is a need to make this important construction material compatible with environmental requirements of the modern sustainable construction industry.

One viable way to increase concrete industry sustainability is to utilize industrial and agricultural wastes. Industrial waste materials, such as fly ash, silica fume, ground granulated blast furnace slag and others have been successfully used in concrete for a long time [1,8]. Recently, agricultural solid wastes (i.e. agro-waste), such as oil palm shell, coconut shell, corn cob, pistachio shell have attracted researchers as a replacement for natural aggregate in structural and non-structural concrete [9-12]. The use of these agro-wastes as total or partial replacement of natural aggregates, which makes up about 60–80% of the volume of concrete [13], represents substantial energy saving, conservation of natural resources, and a reduction in the cost of construction materials. In addition, it solves the disposal problem of agro-wastes helping in environmental protection [14,15].

Therefore, this study represents the keystone for shaping a sustainable pathway for agriculture wastes/residuals. It will proofing the feasibility of incorporating agro-wastes in construction materials, and reaching the utilization of these bio-based construction materials to develop innovative products with a commercial value. The study investigates the potential of using agro-waste to mitigate shrinkage cracks.

EXPERIMENTAL WORK

The experimental plan was designed to investigate the effect of incorporating fibrous agro-wastes on the shrinkage performance. A series of mixtures were prepared to identify the optimum content of the fibrous agro-waste to minimize cracking due to shrinkage.

Materials

GU hydraulic cement according to the CSA-3001-03 was used as the binding material. The used fine aggregate was a natural riverside sand with a fineness modulus was 2.70 according to ASTM C136 (2014), specific gravity and water absorption of 2.51 and 2.73% determined by ASTM C 128 (2015), respectively. The coarse aggregate was siliceous/calcareous aggregates with a maximum size of 20 mm (3/4 inch), specific gravity of 2.697 kg/m3 and water absorption of 0.6%. Fibrous agro-waste (Fig. 1) was added to the mixtures at rates 3%, 5% and 7% as a replacement of sand. For all mixtures, water to binder ratio of 0.45 was used.

Fig. 1: fibrous agro waste (known as Miscanthus).

Samples preparation and testing

Concrete cylinders of Ø100mm×200mm were prepared to measure mechanical properties. All specimens were made and cured according to ASTM C192 "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory". Indirect tensile strength were measure for replicate of each mixture at different ages according to ASTM C496 "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens". For shrinkage, an instrumented ring test was performed similar to previous work [16] to quantify the restrained shrinkage behaviour, cracking age and width, for mixtures with and without fibrous agro-waste. Figure 2 shows the dimensions of the used concrete ring specimen. The specimens were allowed to dry from sides only. Four strain gages were installed at the mid-height on the inner circumference of the steel ring to measure the strain until the concrete ring cracked. After that, measurements of the cracking widths were taken for a continuous 6 hours.

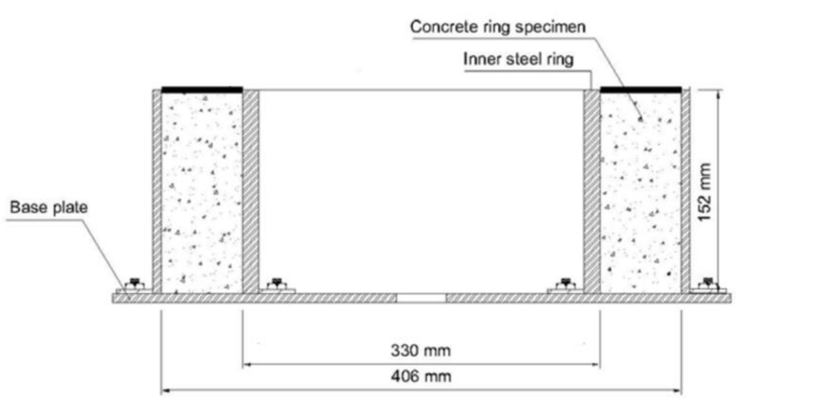

Figure 2. Ring test to evaluate cracking time and increase in crack width

Results and discussion

Figure 3 shows the tensile strength results for mixtures with and without fibrous agro-waste. It was clear that increasing the fibrous agro-waste content resulted in a higher tensile strength. The higher the added fibrous agro-waste content, the higher the achieved tensile strength. For instance, adding fibrous agro-waste at rates 3% and 7%

increased the tensile strength for the mixtures with about 12% and 66% compared to the control plan mixture. This could be attributed to the ability of the fibrous agro-waste to bridge cracks and resist crack propagation in the matrix. Moreover, the variations in fibrous agro-waste lengths and sizes provided resistance for cracks propagation at various levels.

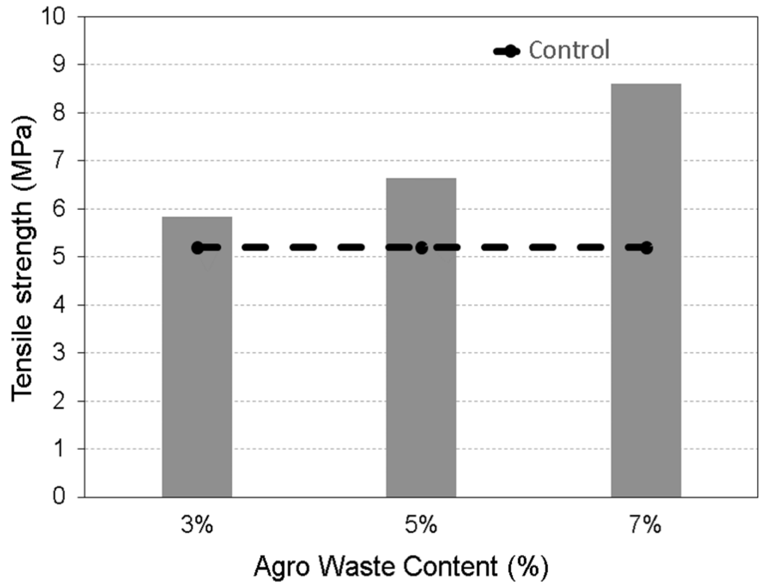

Figure 3. Tensile strength results for mixtures with different fibrous-agro-waste contents

On the other hand, exposing the specimens to a drying condition (Temperature 23℃ and relative humidity = 45%) will lead to moisture loss. This will lead to drying shrinkage and development of internal tensile stresses. Once, these stresses exceeded the tensile strength of the concrete, cracks will be formed. The longer the drying period, the higher the shrinkage and consequently the crack's width will increase. Figure 4 shows the changes in the initial crack formation time for various mixtures.

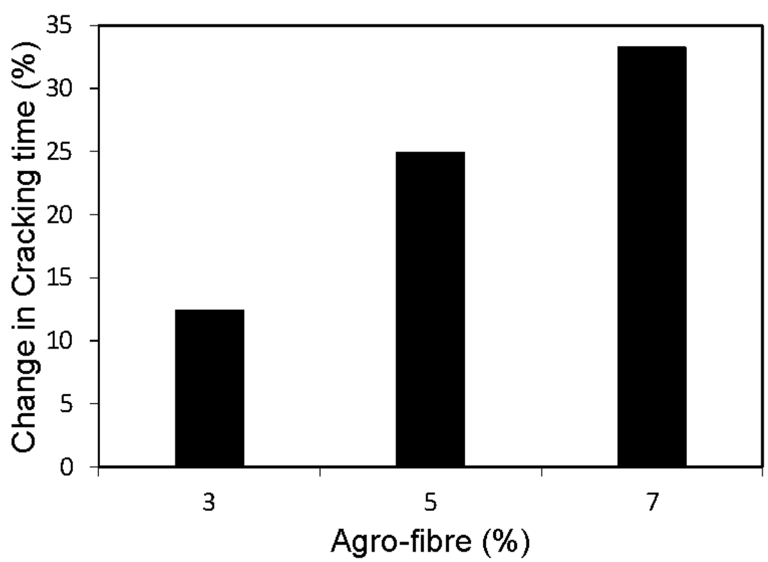

Figure 4. Changes in cracking time at various fibrous agro-waste contents

As expected, the higher the fibrous agro-waste content, the longer the needed initial time for cracks formation. This is expected as adding fibrous agro-waste resist crack propagation at various levels as explained earlier. This increased the concrete resistance for crack formation. This was confirmed by the good correlation between tensile strength and cracking age for various mixtures (R2> 0.9) illustrated in Fig. 5.

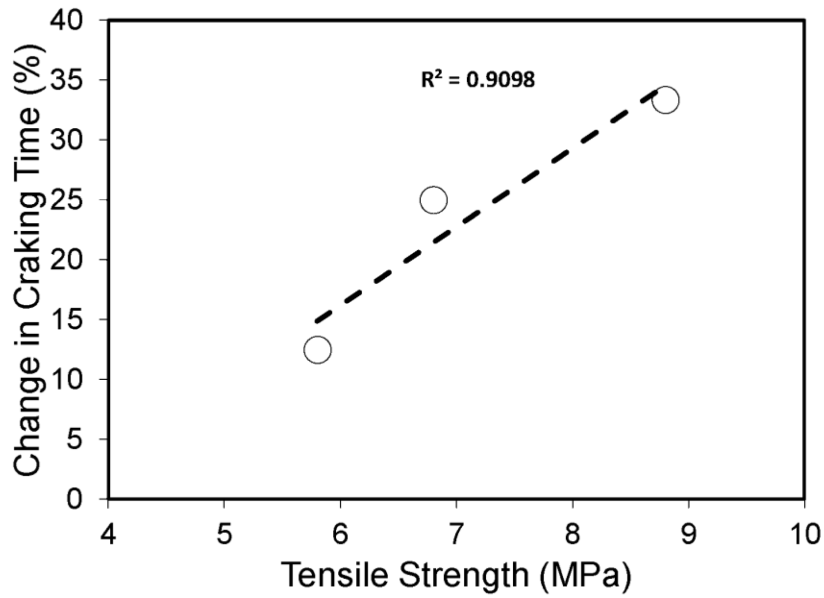

Figure 5. Correlation between changes in cracking time and tensile strength for mixtures with various fibrous agro-waste contents

Figure 6 illustrated the change in the crack width rates for mixtures with various fibrous agro-waste contents. It was clear that the increase rate in the crack width was high at the initial period, then it started to decrease with time. For instance, mixture with 3% fibrous agro-waste exhibited an increasing rate in crack width increase up to 7 hours after the initial crack, then the rate started to decrease. On the other hand, mixtures with higher fibrous agro-waste contents achieved a decreasing rate earlier. For instance, mixtures with 7% fibrous ago-wastes achieved the decreasing rate after 5 hours only.

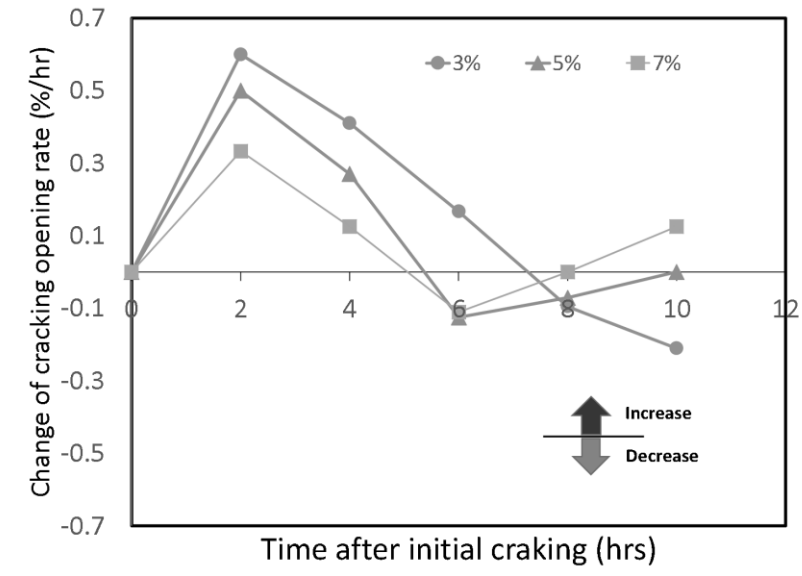

Figure 6. Changes of crack opening rate for mixtures with various fibrous agro-waste contents

CONCLUSION

Recycling and reusing agro-waste in construction materials has a high potential. A key point to achieved adequate performance is select the appropriate type of agro-waste and optimizing the mixtures. This optimization will maximize the benefits for all features of the used agro-waste. This paper showed that fibrous agro-waste had a high potential to be recycled in concrete mixtures. It will provide a kind of reinforcement leading to high resistance for cracks induced due to shrinkage.

Acknowledgements. Authors would like to thank irda for providing fund and in-kind contribution for the carried research project.

REFERENCES

1. Meyer, C. (2009) "The greening of the concrete industry," Cement and Concrete Composite, Vol. 31, No. 8, pp. 601–605.
2. Mehta, P. K. and Monteiro, P. J. M. (2006). Concrete: Microstructure, Properties, and Materials. 4th edition, New Jersey: McGraw-Hill; 704 p.
3. GhaffarianHoseini, A., Dahlan, N. D., Berardi, U., GhaffarianHoseini, A., Makaremi, N. and GhaffarianHoseini, M. (2013) "Sustainable energy performances of green buildings: A review of current theories, implementations and challenges," Renewable and Sustainable Energy Reviews, Vol. 25, pp. 1-17.
4. Mehta, P. K. "Greening of the concrete industry for sustainable development," Concrete International, Vol. 24, No. 7, pp. 23-28.
5. Liew, K.M., Sojobi, A.O. and Zhang, L.W. (2017) "Green concrete: Prospects and challenges," Construction and Building Materials, Vol. 156, pp. 1063-1095.
6. Meyer, C. (2009) "The greening of the concrete industry," Cement and Concrete Composites, Vol. 31, No. 8, pp. 601-605

7. Turk, J., Cotič, Z., Mladenovič, A. and Šajna, A. (2015) "Environmental evaluation of green concretes versus conventional concrete by means of LCA," Waste Management, Vol. 45, pp.194-205.
8. Federico, L. M. and Chidiac, S. E. (2009) "Waste glass as a supplementary cementitious material in concrete - Critical review of treatment methods," Cement and Concrete Composite, Vol. 31, No. 8, pp. 606-610.
9. Khankhaje, E., Salim, M.R., Mirza, Hussin, M.W., Khan, R. and Rafieizonooz, M. (2017) "Properties of quiet pervious concrete containing oil palm kernel shell and cockleshell," Applied Acoustics, Vol. 122, pp. 113-120.
10. Kanojia, A. and Jain, S. K. (2017) "Performance of coconut shell as coarse aggregate in concrete," Construction and Building Materials, Vol. 140, pp. 150-156.
11. Pinto, J., Vieira, B., Pereira, H., Jacinto, C., Vilela, P., Paiva, A., Pereira, S., Cunha, V. M. C. and Varum, H. (2012) "Corn cob lightweight concrete for non-structural applications," Construction and Building Materials, Vol. 34, pp. 346-351.
12. Shafigh, P., Mahmud, H.B., Jumaat, M.Z. and Zargar, M. (2014) "Agricultural wastes as aggregate in concrete mixtures – A review," Construction and Building Materials, Vol. 53, pp. 110-117.
13. Badur, S. and Chaudhary, R. (2008) "Utilization of hazardous wastes and by-products as a green concrete material through S/S process: A review," Review on Advanced Materials Science, Vol. 17, No. 1–2, pp. 42-61
14. Ramezanianpour, A. A., Mahdikhani, M., Ahmadibeni, G. and Medial, R. M. (2009) "The effect of rice husk ash on mechanical properties and durability of sustainable concretes," International Journal of Civil Engineering, Vol. 7, No. 2, pp. 83-91.
15. Harimi, M., Harimi, D. J., Kurian, V. J. and Bolong, N. (2005) Evaluation of the thermal performance of metal roofing under tropical climatic conditions, SBO: 2005 World Sustainable Building Conference, Tokyo, Japan. September, p. 709–16.
16. Soliman, A. (2014) "Early-Age Shrinkage of Ultra High-Performance Concrete: Mitigation and Compensating Mechanisms", PhD thesis, Western University, Canada