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PERFORMANCE OF AGRO-CONCRETE UNDER AGGRESSIVE AGRICULTURE ENVIRONMENTS

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ABSTRACT The life-cycle of any concrete structure depends on its type, the used material, the exposure and operation conditions, as well as other factors. Consequently, various modes and mechanisms of concrete deteriorations can be detected, such as shrinkage cracking, loss of bond and spalling. Among these causes of structural degradation, bio-deterioration is a common mechanism in agriculture concrete structures such as agricultural effluents collecting, storage and treatment structures. Organic acids, ammonium, and gases are generated as a result of microorganisms' activities, lead to a very aggressive environment for the cementitious materials. On the other hand, the use of biomass and agricultural residues in the concrete could lead to both, reduce footprint of concrete structure and contribute to a circular economy model. Hence, this study investigates the performance of agro-concrete mixtures exposed to a simulated aggressive agriculture environment. Various agriculture biomass were added as a partial replacement of natural aggregate at rates 10%, 15%, and 20% by volume. Residual strength, mass loss and ultrasonic pulse velocity tests were conducted to evaluate agro-concrete degradation over the investigated period. Results showed that increasing the agriculture biomass content affected the performance. However, finding the optimum content of such residuals increases the potential of their use to achieve sustainable agro-concrete with adequate performance.

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

INTRODUCTION In the last decade, the population has increased, resulting in increased demand for unpredictably constructed structures and natural resources. Physiological Needs, such as food, are at the bottom of Maslow's hierarchy of human needs [1].As a result of this need, agriculture is one of the most productive industries. As a result of this requirement, agriculture is one of the most well-functioning industries.

The expansion of the agricultural sector resulted in issues such as agricultural waste management [2, 3]. Animal waste, such as compost, food processing waste, crop waste, and dangerous and poisonous plant waste, is an example of various agro-waste types (liquids, slurries, or solids). One of the critical causes for waste management's difficulties is the range of agro-waste [4]. According to the information published by F.A.O. (United Nations Food and Agricultural Organization), regardless of the type of products of the agricultural industry, the products have always had an upward trend. This growth in the industry's production volume, along with a substantial rise in overall agricultural waste materials, creates waste management challenges[5, 6]. As the population grows, there will be a greater need for construction. When the concrete market grows, so does the demand for critical ingredients such as sand and cement.

Excessive mining and processing of these components cause irreversible environmental damage. [7] As a result, despite their effectiveness, waste management options such as burning and burying [8] are ineffective due to inefficient energy and financial resources[9]. Along with these alternatives, using these wastes as an alternative to the critical components of building materials, such as replacing agricultural residues in concrete instead of coarse and fine aggregates, has offered numerous advantages, including financial, energy, and environmental benefits[10]. Another drawback of this substitution is that it reduces landfill and construction material costs[11]. This research looks into some of the roles that agricultural waste can play in the building industry. These functions may be analogous to removing a portion of construction material, such as fine aggregate in concrete.

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.

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%. According to CSA-3001-03, General Used The used agro-waste was a fine residual from black spruce (Fig. 1) which grows across a broad transcontinental range from Alaska (United States) to Newfoundland (Canada) [12]. Mixtures with varying cement contents were prepared in this study based on proportion guidance stated by the ACI [13]. Agro-waste was added a partial substitution of sand by volume at rates of 0% up to 20%. For all mixtures, water to binder ratio of 0.45 was used.

Fig. 1: Agro-waste (known as fine residual from black spruce).

Mixing procedure

The mixing process was carried out after reviewing related literature[14, 15]. To begin, the dry mixture components (cement, fly ash, and agro-waste) were mixed for 1 minute without the addition of water to ensure a homogeneous distribution. After that, the mixing water was split into two halves. The first half of the mixing water was steadily applied to the mixture when mixing for another minute. The second half was then added and combined for 1 minute more. After applying the entire volume of mixing water, the mixture was allowed to sit for 1 minute. The mixture was then mixed for another 2 minutes before sampling. The flowability of all tested mixtures was determined continuously with different mixing water additions, with the goal of achieving the optimal typical flowability in the range of 150 - 200 mm as suggested by[13].

Samples preparation and testing

Results and discussion

Flowability findings for all measured cementitious mixtures are seen in Figure1. The water content of all mixtures was calibrated to achieve acceptable flowability in the 150-200 mm range. According to[13], the flow values ranged from 151 to 189 mm, under the usual flowability band. Growing the cement content while retaining the same fly ash content decreased flowability at the same water volume. For example, rising the cement content resulted in a reduction in flow from 182 mm to 151 mm. Both mixtures, however, remained within the appropriate limit.

In contrast, replacing sand with agro-waste reduced the amount of water required to achieve the same flowability range as control mixtures (Figure2). This is due to two compensating consequences caused by fine agro-waste: increased water demand and the release of entrapped water. The addition of such fine agro-waste increases the surface area of the particles in the mixtures, resulting in a greater need for water. Simultaneously, fine agro-waste particles will fill voids between binder particles and release entrapped water[14]. As a result, more free water is required for lubrication and flowability in the measured cementitious mixtures.

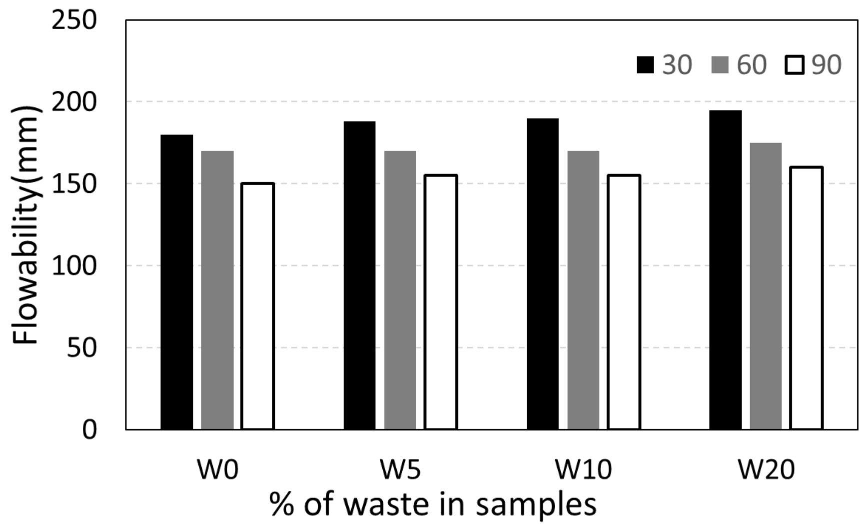

Fig 2. Flowability results for all tested cementitious mixtures

The compressive intensity findings for tested cementitious mixtures from 3 to 28 days are summarised in Figure 3. In general, the lower the cement quantity, the lower the strength achieved. This is since lowering the cement content reduces the amount of calcium hydroxide (C.H.) in the mixture. As a result, the rate of pozzolanic reactions between silicate from fly ash and C.H. to form calcium silicate hydrated (C.S.H.) (a binding material) slows [16]. As a result, strength gain values for Group 30 and 60 mixtures were predicted to be weaker than those for Group 90 mixes.

It was apparent that the strength of mixtures containing agro-waste materials declined as the volume of agro-waste increased. Furthermore, the influence of agro-waste on strength was visible in rich mixtures (high cement content, 90 kg/m3) (Figure 3). In contrast, differences in strength due to agro-waste addition were negligible for lean mixtures (i.e., low cement content 30 kg/m^3) (Figure 3). As a result, the greater the cement content, the greater the reduction in strength caused by agro-waste addition. This is due to two factors: the high water/powder ratio and the low C.H. in lean mixtures. However, increasing the cement content remains an outstanding option for overcoming the strength loss if necessary. For example, raising the cement content in mixtures containing 20% agro-waste resulted in a 300 percent improvement in achieved compressive strength.

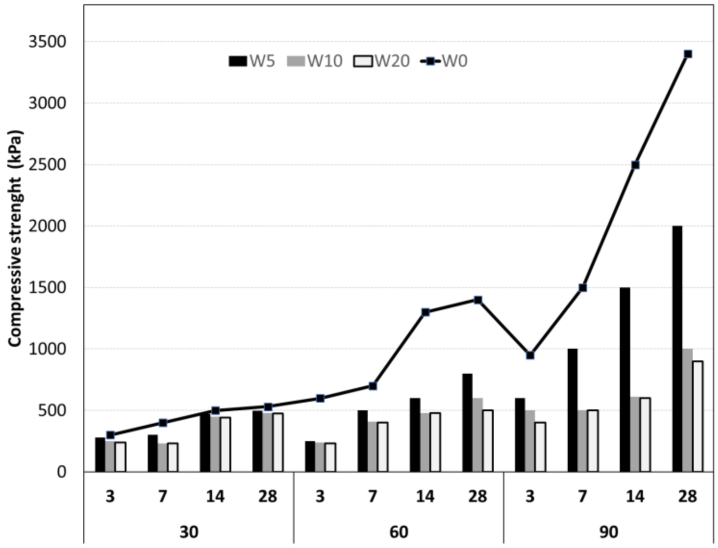

Fig 3. Compressive strength development for tested cementitious mixtures

The number of cycles in the Sulphate solution, mass loss, and residual strength was used to test cementitious mixtures' efficiency with and without agro-waste under Sulphate exposure. The number of cycles endured by cementitious specimens immersed in Sulphate solution is shown in Figure 4. The pattern does not hold up with all mixtures. The higher the agro-waste content, the less the continuous periods for mixtures with heavy cement content. For example, mixtures with the highest cement content and incorporating agro-waste contents of 5% and 20% lasted 15 and 11 cycles before failing, respectively.

The cyclic dry and wet phases in the sodium Sulphate solution are other parameters expected to contribute to the deterioration of cementitious specimens. Volume variability is caused by repeated wet and dry cycles (i.e., dry shrinkage and wet expansion deformation). When the tensile strength of the cementitious mixtures is exceeded, this deformation will cause internal stresses that will contribute to micro cracking. The developed cracks would intensify shrinkage and swelling deformation, resulting in more crack propagation, internal structure breakage, and, eventually, specimen failure[17].

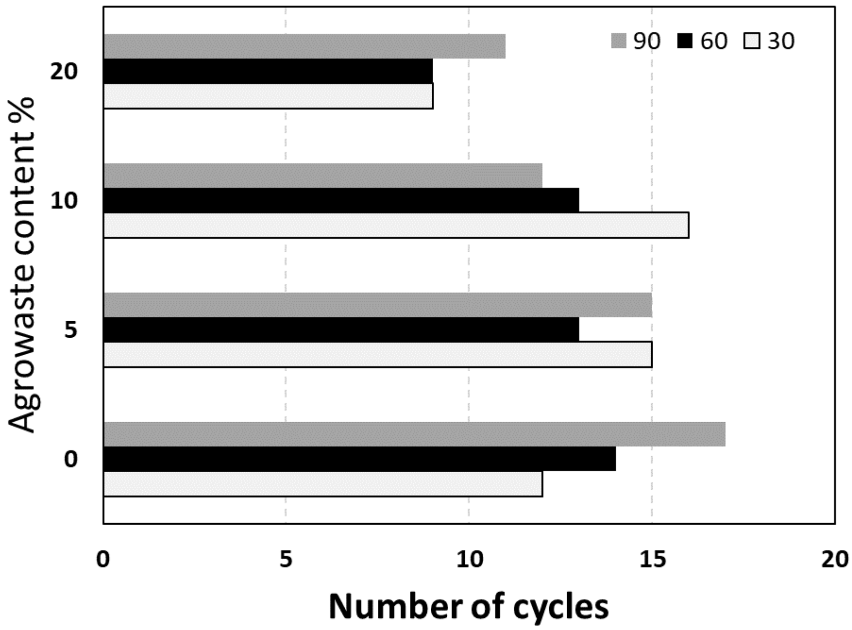

Fig 4 .Numbers of sustained cycles in sulphate solution for all cementitious mixtures

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 proofed the possibility to produce cementitious mixtures with agro-waste while achieving adequate fresh and hardened properties and durability performance.

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