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Assessing benefits of pre-soaked recycled concrete aggregate on variably cured concrete

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HIGHLIGHTS

- Entraining water in concrete using RCA absorption proposed.
- Neither RCA type behaved as a conventional internal curing source.
- RCA types have different effects on RCA-concrete properties.
- Saturated RCA can benefit concrete under non-ideal curing conditions.
- Tensile strength and modulus of elasticity are negatively affected by RCA.

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ABSTRACT

Coarse recycled concrete aggregate (RCA) is a variable material, and that variability can often make it less desirable for usage in concrete infrastructure. One consistent characteristic of RCA however, is a higher absorptive capacity when compared with natural aggregate (NA). Due to this higher absorptivity, there is potential for the RCA to provide some internal curing-like benefits when it is properly prepared prior to batching into concrete. Internal curing involves the entrainment of water in reservoirs within the concrete which is drawn from the reservoirs at a beneficial point of the cement hydration process. Internal curing in concrete has been found to have many benefits including reducing the negative effects of poor external curing.

In this research, two types of saturated coarse RCA have been used to study the effects of different curing practices on the performance of the concrete. Particular emphasis has been placed on those properties that are critical for concrete pavement design. Two curing regimes are used in order to better understand the impact of curing practices on saturated RCA concretes.

The two RCA sources oppositely affected the compressive strength: RCA 1 increased strength while RCA 2 caused a decrease. Saturated high absorption RCA appeared to provide some benefit in terms of compressive strength loss under poor curing conditions. Both RCA types had similar negative effects on the tensile strength and elastic modulus of the concretes in comparison to natural aggregate.

1. Introduction

The use of recycled concrete aggregate (RCA) as a building material is gaining popularity in Canada's construction industry. The use of RCA in Ontario road construction projects more than doubled between 1991 and 2006, and continues to grow. While Canada is a large and resource-rich country, the population distribution makes it such that the availability of aggregate in high density areas is becoming strained [1]. This, combined with increasing demands on landfills and the recognition that it is a viable construction material has made RCA a more desirable building material.

RCA is a construction material produced by crushing previously cast concrete from a variety of structures including roads, bridges, and buildings. It can also come from material that is returned to ready-mix plants. In this research, both types are used. The products of this crushing can then be used again in the production of new concrete as a granular fill-type material or as a graded replacement of coarse aggregate.

RCA is a material which has a huge supply which consists of every existing concrete structure which will be demolished at some point. However, one of the prominent issues associated with

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this large supply is that the material which each concrete structure is composed of is different. These differences depend on such things as structural requirements, available materials, the year in which the concrete was produced, and many other variables [19]. This wide variation in concrete composition results in a similar variation in the RCA which is produced when the concrete is crushed. The wide variation in RCA results in some materials with intrinsic properties which lend themselves well to the production of high quality concrete and other materials which could be detrimental to the performance of any concrete it was included in. Between these two RCAs exists a wide spectrum of RCA which performs variably in concrete. While some of the RCAs on this spectrum may not be feasible for use in concrete, they are often found to be acceptable for use as granular material in fill or base applications.

Based on the inherent variability of RCA, concrete producers in Canada often elect to avoid the use of RCA completely or to limit its use to lean concrete or other similar low-demand applications. Several studies have indicated that the use of RCA in concrete can result in a loss of compressive strength and durability characteristics, including those by Maruyama and Sato [2], Fonseca, de Brito, and Evangelista [3], and Olorunsogo and Padayachee [4]. Given the findings of this previous research, limiting the use of RCA is often considered as a reasonable way to limit the risk associated with the material. However, this practice results in the loss of significant value in the cases where a given RCA actually has properties which are beneficial to the production of certain concretes.

Previous work at the University of Waterloo (UW) produced an RCA classification framework which served to classify different RCAs according to their best potential use or application. These applications ranged from use in reinforced structural concrete to use only as a fill material. The framework was developed such that classification depended largely on independent aggregate tests in order to accommodate the common situation in which the original source of an RCA is unknown. The framework developed is an excellent starting point for the development of a tool which could be used industry-wide to achieve much more effective use of existing and future RCAs. [5]

In order to further develop this framework, this research aimed to expand upon the currently existing knowledge base by studying the effects of various RCAs in concrete in terms of their internal curing benefits. Internal curing (IC) is the practice of casting concrete with reservoirs of water entrained within the concrete mixture. The internal reservoirs become effective during the hydration process of concrete after a significant portion of the mixing water is consumed. This creates a moisture gradient which draws the water from the reservoirs into the concrete paste matrix. The presence of this extra water allows for a more complete hydration reaction of the concrete.

One benefit of IC occurs when the internally entrained water helps to alleviate the negative effects of drying by replacing any evaporated water prior to the desiccation of the concrete and the onset of shrinkage cracks. In this case IC helps to alleviate the effects of non-ideal curing practices [6].

Internal curing is often employed through the use of lightweight aggregate (LWA). Lightweight aggregates are lightweight in part because of their relatively large void content which makes them ideal materials for absorbing water. The amount of the LWA included in IC concrete is generally proportioned in order to provide enough water for full hydration. The particle size of the LWA is generally small enough such that it is dispersed throughout the concrete. This results in a small enough spacing factor that the entrained water can permeate through all parts of the concrete paste matrix [12].

Despite the aforementioned variability of RCA, one property which is consistent is an absorption capacity which is larger than most natural aggregates (NA) used for production of concrete. For reference, the Cement Association of Canada states that the typical absorption capacity range for coarse concrete aggregate is 0.2–4%, and 0.2–2.0% for fine concrete aggregate [7]. Absorption capacities for coarse RCA in previous research range from 3% to 9%, and up to 16% in fine RCA. This research considers only coarse RCA.

Because of this characteristic, part of determining the most effective use of RCA may include utilizing this characteristic in order to achieve some IC benefits in a given RCA concrete. These benefits may improve the characteristics of an acceptable mix, or potentially counteract some of the negative qualities associated with the use of some RCAs in concrete.

2. Objectives

The purpose of this study is to study the effects of poor curing conditions on concretes batched with saturated coarse aggregates, including both virgin aggregate and RCA. Since the RCAs being studied have higher absorption capacities, they will contain more water which is not initially part of the mixing water. The goal is to determine whether this entrained water can provide benefit to concrete which is cured in less than 100% relative humidity environments. The concrete properties to be focused on are fresh (slump, air content, fresh density) and hardened properties (compressive and tensile strength, and modulus of elasticity).

The effects are studied from the perspective of IC benefits, which have been researched extensively. While the use of recycled aggregate purely as an internal curing agent may not be feasible, internal curing-related benefits could potentially be achieved by incorporating RCA into concrete.

2.1. Variables

2.1.1. Aggregate

Mixtures incorporating two different sources of recycled aggregate and one virgin aggregate are each tested at 100% aggregate saturation. For each RCA mixture, the RCA represents 100% of the coarse aggregate. These mixtures are compared across two different curing regimes so that the effects of differential curing can be assessed for each mixture.

The recycled aggregate sources are referred to as RCA 1 and RCA 2. RCA 1 was produced through the crushing of non-structural concrete from the Region of Waterloo. The concrete came from demolished local structures including curbs, gutters, and sidewalks. In most cases this concrete was available due to roadway expansion and not due to failures. It should also be noted that the available material was very good in both quality and consistency.

RCA 2 was produced through the crushing of concrete which was returned to a concrete producer's plant, and not used in service. The concrete could have been returned for various reasons including improper mix proportions, but was most commonly "left-over" concrete which remained in the truck at the conclusion of a concrete pour. This material would be washed from the concrete trucks into piles which would be crushed when a sufficient amount had accumulated. Both RCA sources were graded to satisfy the MTO requirements for concrete coarse aggregate, outlined in OPSS 1002 [8].

According to the previously mentioned classification framework, RCA 1 was classified as Class A2 (or Class A1), and RCA 2 was classified as C. According to the framework, this implies that RCA 1 is "high quality" and would be suitable for use in structural