The Sustainability of Concrete for Use under Different Loading and Environmental Conditions

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Abstract

The objective of this study explores the sustainability of different concretes for use under different loading and environmental conditions in the construction and civil engineering industries. This study could have significant positive implications to inspire readers' more comprehensive thought and inspirations obtained from findings for our imitations. Desktop research is preliminarily adopted and an experiment is used. Thirty percent recycled coarse aggregate generally provides superior results compared to 30% recycled fine aggregate. Based on the research undertaken, it can be concluded that using recycled coarse aggregate in new construction and civil engineering projects just makes good sense.

Keywords: Concrete, Sustainability

1 Introduction

Although concretes made from gypsum and limestone have been used for thousands of years, modern concrete was only introduced 200 years ago (Winter 2012). Since that time, concrete has become ubiquitous in virtually all construction and civil engineering projects. This extensive usage has provided a growing body of scholarship concerning concrete's optimal applications in various scenarios including differences in loading and environmental conditions. The purpose of this paper is to identify the sustainability of different concretes for use under different loading and environmental conditions in the construction and civil engineering industries today. The paper first provides a review of the relevant literature concerning these issues, followed by a description of the experimental methodology used, and the results obtained thereby. Finally, a discussion concerning these issues is followed by a summary concerning the optimal concrete that should be used for sustainability under different loading and environmental conditions in the construction and civil engineering industries today.

2 Literature Review

The respective properties and applications of the three concretes of interest (i.e., partial cement replacements, recycled fine aggregate, and recycled coarse aggregate) mean that these materials have different optimal uses depending on the construction or civil engineering setting. There is a growing body of scholarship, though, that indicates recycled fine and coarse aggregates represent a viable alternative for many applications. For example, a study by Hmar (2017) found that there are increasing quantities of waste materials that are generated by the construction industry, and identifying

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opportunities to recycle these materials represents an important step towards developing sustainable building practices. In this regard, Hmar (2017) advises that, "Recycling of these construction waste aggregate (recycled aggregate) can play a vital role in economical as well as natural resources". In fact, recycled aggregates are playing an increasing vital role in reducing the environmental impact of major public works projects and additional applications continue to be identified (Booker 2011).

The production processes for fine and coarse aggregates are essentially the same, differing only in the extent to which the former is processed more than the latter (Hmar 2017). In either case, the use of recycled aggregates just makes good business and environmental sense because both are produced from "aged concrete that has been demolished and removed from foundations, pavements, bridges or buildings [and] crushed and processed into various size fractions" (Hmar 2017).

Moreover, the use of recycled aggregates has also assumed growing importance in recent years because the global supply of natural aggregates for concrete applications is finite and is diminishing rapidly (Nili et al. 2019). In this regard, Nili et al. (2019) emphasize that, "Today, the use of recycled aggregates as a substitute for a part of the natural aggregates in concrete production is increasing. This approach is essential because the resources for natural aggregates are decreasing in the world." Using recycled aggregates for new concrete applications is also more cost effective, making their use a win-win for the construction and civil engineering industries today.

Assuming that using partial cement replacements for new building projects results in the same carbon footprint as the original manufacturing and transportation processes that were involved, it is therefore also important to determine which type of recycled aggregate is best suited for different applications and these issues are discussed in the experimental methodology section that follows below.

3 Methodology

Drawing on the seminal work by Hmar (2017) who investigated the respective properties of recycled aggregates, the experimental method involved analyzing the percentages of recycled aggregates obtained from a nearby demolished building that could partially or completely replace natural aggregates in terms of their weights (in this case, 0%, 30%, and 100%). In addition, the cast concrete cylinders and cubes use the various percentages of aggregates which were then subjected to laboratory testing with respect to, water absorption, aggregate impact and aggregate abrasion values. The respective properties of natural aggregate concrete (NAC) versus recycled fine and coarse aggregate concrete were evaluated with respect to their compressive strength, workability, and tensile strength. The experimental methodology also compared various properties of the coarse and fine aggregates with respect to particle size distribution and compressive testing.

4 Results

The results of this analysis showed that concrete that contained as much as 30% recycled aggregates exhibited the same strength as conventional concrete; however, additions of recycled aggregates beyond this limit is not recommended since it would make the resulting material nonconforming to specifications for water absorption and impact value. The respective cube compression strength of natural aggregate compared to 30% replacement and 100% replacement of coarse aggregate is depicted in Figure 1.

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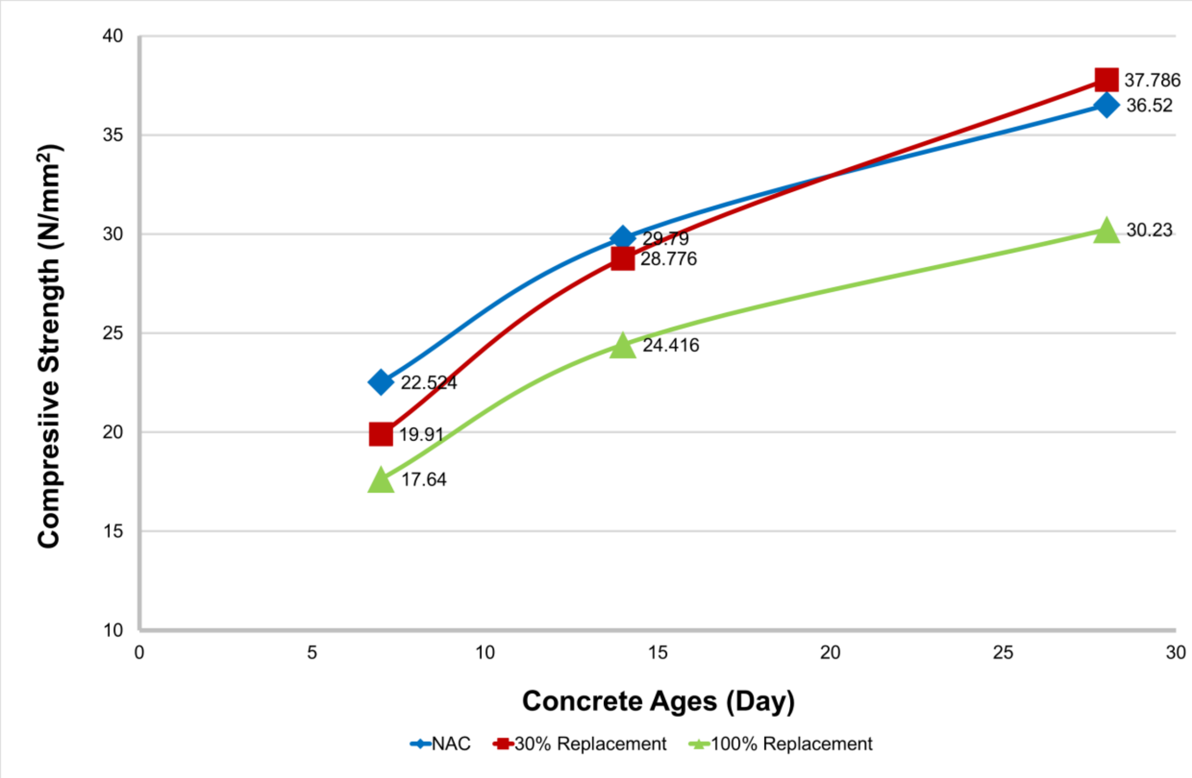

Figure 1: Comparison of cube compression strength of NAC (blue line) versus 30% replacement (red line) and 100% replacement (green line) with recycled coarse aggregate.

Likewise, the respective split tensile strength of natural aggregate compared to 30% replacement and 100% replacement of recycled coarse aggregate is depicted in Figure 2.

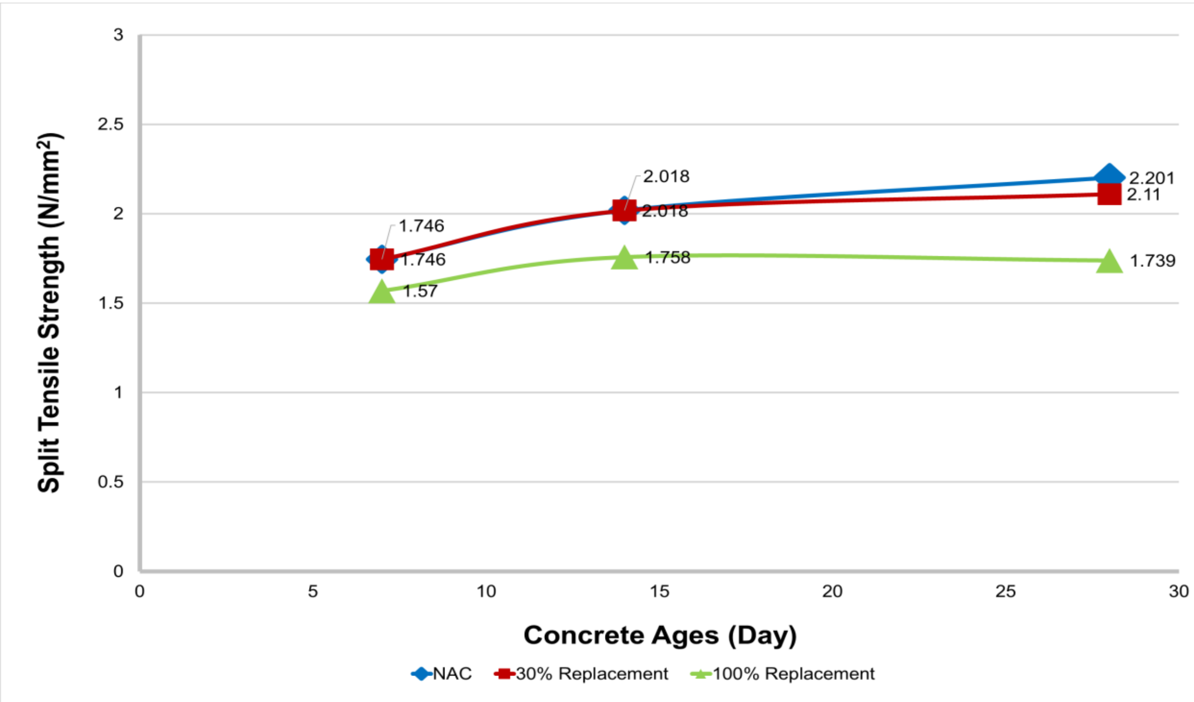

Figure 2: Comparison of split tensile strength of NAC (blue line) versus 30% replacement (red line) and 100% replacement (green line) with recycled coarse aggregate.

5 Discussion

Based on the assumption that partial cement replacements require the same amount of resources with the corresponding carbon footprint as the original materials that were used in a construction or civil engineering initiative, the question then moves to whether recycled fine aggregate or recycled coarse aggregate represents the optimal solution for most projects. Based on the findings that emerged from the experimental methodology that was described above, a 30% recycled coarse aggregate generally provides superior results compared to a 30% recycled fine aggregate (results not shown). This finding, however, is situation-, resource- and time-dependent and other approaches, including partial cement replacements, may be required.

6 Conclusions

This paper shows that the use of recycled aggregates for cement applications has assumed new importance and relevance in recent years as the environmental impact of producing new concrete has become more apparent. In addition, the research also showed that properly manufactured and applied, recycled aggregates can not only reduce this environmental impact, they can also provide the same attributes as conventional concrete as a fraction of the original cost. Finally, although every engineering setting is unique in some fashion and partial cement replacements or recycled fine aggregates may be required, the research also showed that recycled coarse aggregates generally provides superior results compared to recycled fine aggregates and as much as 30% of conventional concrete can be replaced using this technique, especially if there are demolition projects underway nearby. For example, a significant percentage of the waste concrete that is generated by demolishing an office building can be recycled into public work projects such as highways or private enterprises including a new office building on the same site. In summary, using recycled coarse aggregates in new construction and civil engineering projects just makes good sense.

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