Recyclable Waste Material as Substitute Aggregate in Concrete

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Trash pollution is a serious problem that the world is facing and while there are current efforts to clean up the environment, there still exists the issue of what to do with the trash once collected. Waste material, especially plastic, is littering the ocean and poses a serious threat to wildlife. The construction industry makes a good effort of trying to limit its negative impact on the environment, but it can potentially solve the problem of pollution using one specific material, concrete. The best part about concrete is that its compressive strength can be manipulated by adding or removing certain materials in the mix. There are certain aggregates, such as plastic and glass, that are not currently being used in concrete mix designs, but could be added and only slightly alter the concrete's compressive strength. This paper explores and tests the results of adding plastic and glass into concrete mix. The results will shed light on the idea of cleaning up the environment by putting waste material into concrete and drastically altering the problem of trash pollution.

Keywords: Concrete, Pollution, Compressive Strength, Construction, Recyclable, Aggregate, Concrete Mix

Introduction

There are two specific classes at Cal Poly that, after taking them, sparked an interest in finding ways to be environmentally friendly in construction. The classes are called *Sustainability and the Built Environment* and *Green Building*. Until you are exposed to the reality of just how much trash the human population creates, the gravity of the problem goes somewhat unnoticed by the general public. In 1997, scientist Charles Moore discovered what is known as the great Pacific Garbage Patch. It is, according to countless press and TV reports, a "trash vortex," "the world's largest rubbish dump," and a "vast mass of floating debris" midway between Hawaii and California. It is mostly an unstrained consommé of small bits of floating plastic. And the patch Moore found isn't the only one. A similar accumulation of plastic particles—which include weathered fishing line, Styrofoam, wrappers, and raw resin pellets—has shown up in the North Atlantic Ocean (Kaiser). While the best solution to fixing this would be to cut off the waste generation at source before it ends up in the ocean, we still have to clean it up and find a place for it.

Now, as you can imagine, the construction industry uses a lot of material and natural resources for its operations. In fact, the construction industry is responsible for 50 percent of the consumption of natural raw materials, 40 percent of the total energy consumption. Due to this amount of consumption, it is also responsible for almost half of the total industrial waste generation Concrete is the most widely used construction material today. It is estimated that roughly 25 billion tons of concrete are produced globally each year, or over 3.8 tons per person per year (Marinković).

With so much concrete being produced annually and the incredible amount of trash that is cluttering the environment, using that trash and debris as aggregate in concrete sounds like it is at least worth trying. We could potentially use the waste material as aggregate in some cases. To clarify, admixtures are the ingredients in concrete other than cement, water, and aggregate that is added to the mix immediately before or during mixing (Chemical Admixtures). In comparison, aggregate occupies most of the volume of the concrete. It is the stuff that the cement paste coats and binds together (Girard). In 2010, Americans produced about 250 million tons of garbage. 54 percent is gathered in landfills and only about 34 percent is recycled (Bradford). With 25 billion tons of concrete produced every year and 250 million tons of garbage being produced – in the U.S. only – we could essentially solve the problem of trash pollution that the world is currently facing.

In order to test this idea, I made samples of concrete with various waste materials – plastic and glass - added to the mix in order to test the concrete's compressive strength. My hypothesis is that the strength of the altered concrete samples will be very close to that of a normal concrete sample and that we can begin adding waste material into concrete mixes for projects around the world.

Process

In order to test the hypothesis, I first researched which waste materials were most prevalent in the environment. I found that plastic and glass were two of the most common types of waste polluting the world, so I started recycling those materials so that I could add them to my concrete batches. I used the following mix designs for my samples:

Mixture	Quikrete	Water	Additive
Control	**180**	**21**	**0**
Plastic	**180**	**21**	**0.625**
Glass	**180**	**21**	**3**

Table 1. Shows the weight in lbs. used for each material in each mix

Before I poured my batches, I had to determine how much of each material I'd be using. I decided that I wanted to make 4 samples of each mix – 12 samples total – so that I could test the concrete's strength 7 days after the pour and 28 days after the pour. I decided to use Quikrete concrete mix with 3/8 inch aggregate for its easy-to-use characteristic. The cylinders that I'd be pouring my batches into are 6" in diameter and 12" in height, which makes the volume 0.2 cubic feet in size, so 2.4 cubic feet of concrete total. The Quikrete manufacturer specifications state that each 90 lb. bag of Quikrete yields 0.675 cubic feet. I would only need 4 bags of Quikrete to pour all of the batches, but I purchased 6 bags of 90 lb. Quikrete and would use 2 bags for each mix to ensure that I had extra in case an anomaly occurred. The manufacturer's recommendation for the amount of water to use with each bag calculated out to be 13 cups of water, so I poured 26 cups of water into the mixer, but I discovered that it was not enough water as the consistency was very thick and looked unworkable, so I poured 13 more cups of water totaling up to 39 cups of water in each mix.

As per the ASTM standards, when I poured each cylinder by three layers with each layer being rodded 25 times in order to eliminate air bubbles and compact the sample. Also, after each layer and rodding, I tapped the side of the cylinder with the rod to get rid of voids caused by the rodding. After rodding and tapping the third layer, I used the tamping stick to screed off the excess concrete so that the concrete was flush with the top of the cylinder. I wanted to make 2 cylinders for the break on the 7^{th} day and 2 cylinders for the break on the 28^{th} day in case there was an anomaly in my pouring or curing of the concrete. I poured a regular batch first as my control so that I could test the altered samples results against the results of regular concrete. I capped each sample and marked the type and of mix as well as the planned break day on each cap. I noted the time of day and weather conditions during my pour in case of an anomaly; I poured at 8 a.m. in cold and sunny conditions. I then placed my samples in a curing room in lukewarm water where it could cure in a controlled setting.

For my plastic batch, I cut up 15 plastic water bottles into several pieces and placed the pieces into the concrete mixer as it was mixing. The sizes of the plastic particles I used ranged from 1 square inch to 3 square inches and were as thin as a typical plastic water bottle. For my glass batch, I crushed 8 glass bottles into pieces and placed them into the mixer as it was mixing as well. In order to break the glass I placed the bottles into a bucket and dropped a rock on them. This produced glass particle sizes as fine as sand to pieces approximately 2 square inches. I did the same process of pouring and labeling the glass and plastic samples as I did with the regular control sample.

After allowing the concrete samples to cure for 7 days, I went to test the compressive strength of each batch only to learn that the compressive strength test machine broke and was now unusable. At first I thought my experiment was going to be ruined, but I soon realized that I really only needed the final compressive strength of the 28-day samples in order to test my hypothesis. Not having the results of the 7-day samples means that, in a real world application of the mix I created, we would not know how soon we could load the concrete. So, after 28 days, I went to test the last samples at the local Hanson Aggregate plant and thankfully they allowed me to bring my samples to their site and break my samples using their machine. The results of the compressive strength test of each sample is as follows:

Concrete Compression Test			
	Control	**Plastic**	**Glass**
Day 28 – Sample #1 (Break Type)	2,041 (Cone)	1,864 (Shear)	2,063 (Cone)
Day 28 – Sample #1 (Break Type)	2,137 (Shear & Cone)	1,031 (Shear/Columnar)	1,683 (Cone)
Average	2,089	1,448	1,873

Table 2. Shows the results of each compression test at failure. This is measured in pounds per square inch. The break results are shown below each test.

New Knowledge

The strength of the concrete samples was weaker than I expected, but adding aggregate into a concrete mix without also adding more cement will cause this decreased strength to happen. I also believe there was an anomaly in the plastic concrete samples because there is a significant difference in the test results. There a few reasons why this could have happened, one being that the plastic was evenly distributed within one sample while the plastic in the other was not. Assuming the aforementioned anomaly did occur and was the cause of the weaker result, all three mixes were relatively close in compressive strength. So, the results from the compressive strength tests on the 28-day samples show that the plastic and glass mixes are acceptable for non-structural concrete use. Sidewalks, benches, and curbs are some examples of what these concrete mixes can be used for.

Deliverables

This senior project explored the idea of adding recyclable waste material as aggregate in concrete in order to reduce the negative impact that waste has on the environment. This experiment lays the groundwork and opens the door for even more waste materials to be experimented with as aggregate. This experiment, with the specific mix designs used, draws the conclusion that waste material such as plastic and glass decreases the compressive strength, but can be used as aggregate in concrete for non-structural mix designs.

Lesson's Learned

The way Construction Management classes are taught at Cal Poly SLO is what made me choose this senior project topic. The classes are designed to make the student learn the material by physically building or designing what the textbooks talk about, so I wanted to do my senior project on something that was challenging physically and forced me to design, create, and/or demolish. First, the biggest lesson learned was just how sensitive the relationship between the concrete mix design and the compressive strength results really are. Because I decided to use Quikrete for ease of use, all of the manufacturer's recommended mix designs were based on large-scale projects, so I had to use ratios to find the correct mix designs for my experiment. Secondly, I learned that the distribution of aggregate within the samples greatly affect the compressive strength, as was the case for my plastic samples. The lesson learned from that is that by mixing the concrete and plastic in the mixer for too long can cause clumping, so perhaps physically mixing it myself for a shorter period of time could have eliminated that flaw. Lastly, I learned that this experiment has so much more potential for expansion. By completing this senior project, I learned a great deal about how the construction industry can help reduce trash pollution by adding waste material as aggregate in concrete.

Application

The results from the compressive strength test shows that concrete with plastic and glass as aggregate can be used for non-structural uses such as sidewalks and curbs. They can also be used for architectural uses such as park benches, ramps, or sculptures. Although adding these materials is an extra step in the mixing process, it is fairly easy to do and it relatively does not change the workability of the concrete. The idea is that when there is a need for non-structural concrete use that we take trash from the environment and incorporate it into the concrete. Although this specific project will not cause these changes to happen immediately, it isn't to say that more extensive research by industry professionals won't cause it to become implemented in all new construction. The combination of all the current research in recyclables in construction is already causing laws to be made regarding the industry's impact on the environment. The application of the experiment results could possibly have its greatest impact in certain third world countries where there is an excess of waste material littering the environment. We could potentially eliminate two problems at once by building them streets and sidewalks with the waste material found in that same area.

Future Research

This senior project and experiment only tested the affects of plastic and glass as aggregate in concrete. There are plenty of more waste materials found in the environment that can be experimented with, such as different types of metals and rubber. The biggest change I'd make in future research of similar experiments is to not use Quikrete. Not to say that Quikrete is inadequate, but for this type of experiment having total control of the mix design and material ratios would probably greatly improve the results. I did not have proper control of the W/C (Water/Cement) ratio because the bags of Quikrete do not specify the ratio of cement to aggregate. Because I used a premade mix such as Quikrete, if I were to try this experiment again, I could only change the amount of Quikrete and water used as opposed to being able to change the amount, size, and type of aggregate, cement and water. Future research could include paying closer attention to the time that the concrete mixes in the mixer with the waste material to avoid clumping. With so much potential for changes and improvements, future research on adding waste material as aggregate in concrete can lead to great positive impacts on the environment by the construction industry.

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