Developing Concrete for Developing Nations

An Honors Thesis (HONRS 499)

by

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Abstract

In the United States, concrete and concrete masonry have regressed as architectural materials; many designers view them as aesthetically displeasing, and discard it as architecturally unworthy. However, the vast majority of developing nations utilize concrete for its inexpensiveness and simplicity in construction. While both of the characteristics are important, concrete also requires strict codes and careful reinforcement to ensure safely designed spaces, especially in areas that are prone to earthquakes and other natural disaster. Unfortunately, most developing nations lie in regions highly susceptible to such events, but do not take the proper precautions to ensure safety. With proper additives into the concrete composition, the structural properties of the material may be altered so that, even without improvement to the methods of construction, the building will better withstand the forces of disasters.

Acknowledgements

I would like to thank Tony Costello for advising me through this project during the course of the semester. Additional gratitude must be extended for further opening my eyes to the truly humanitarian potential of architecture: a refreshing reminder that the best design is that which is used to serve others.

I would also like to thank Dave Wheeler of Wheeler Corporation, who donated materials and supplies to complete the research. Without his help and knowledge, this research project would have not succeeded as it did.
Author's Statement

In this Senior Honors Thesis project, I further explored how architecture can improve lives in developing countries across the globe. During fall semester 2010, Tony Costello and a small group of students began primitively researching concrete block design and solar kiln prototypes, focusing upon development for Port-au-Prince, Haiti. However, this research was theoretical and left many avenues unexplored. It is from this foundation that I expanded into researching new methods of composing concrete masonry, so that resistance to natural disasters is increased, as well as decreasing cost and energy to build. Such a type of concrete block would be applicable not only to Haiti but also to many developing countries.

As a double major in both Architecture and Spanish, it can be a bit difficult to combine the two without resorting to the stereotypical ‘rural housing/community development’ niche. However, the Haiti elective helped me to realize that instead of focusing on specific countries, I might be able to better improve situations by designing on an international level rather than for a specific locale. In this way, I will be able to realize the ability of architecture to aid others, as well as increase my own knowledge in a specific area of architecture. Like I stated earlier, during a student’s educational career in architecture, the opportunity to focus on one method of construction and material is rare, seeing as architects are expected to be knowledgeable in all areas of construction (but experts in none). Through this thesis project, I will not only be able to focus on one material, but one that is seldom seen as an architectural craft: concrete masonry. There is much to be experimented with in this field because many architects overlook its potential.

Every year, thousands of people perish in natural disasters, and if construction were improved in impoverished nations, this number could be greatly reduced. By experimenting with the addition of recycled and waste material into concrete composition, this research has the potential to not only structurally improve concrete but also to do so in a sustainable and inexpensive manner by eliminating the waste placed into landfills.

Equally important is educating fellow students in disaster design and humanitarian efforts through architecture; therefore, rather than write a research report, my thesis was presented visually in a ‘gallery opening’ in
junction with fellow peer Anne Schnitzenbaumer, and both projects were left on public display*.

For my experimental materials, I chose three different types: recycled plastic ("regrind"), waste paper, and waste shredded rubber ("crumb rubber"), each for its inherent properties. Concrete, structurally, has no ability to withstand tension or torsion forces, meaning that it is incapable of being stretched or twisted without structurally failing. Typically, steel reinforcement is added to compensate for this, but in developing countries, such a luxury is not generally affordable and results in dangerous construction. However, paper, plastic, and rubber all have both tensile and torsion properties, so the addition of each should theoretically better bind the concrete together, resulting in an overall stronger block.

Much of the semester was spent gathering materials, which were difficult to locate regionally and in such small quantities. (Many companies only place order by the ton; I needed but 5 pounds.) Luckily, through networking and several phone calls, I contacted Dave Wheeler of Wheeler Corporation, a concrete block manufacturing plant in Shelbyville, Indiana. He in turn was able to direct me to local companies that produced the proper plastic regrind and rubber crumb that would be best suited for concrete additives.

After gathering materials, I reconstructed the makeshift kilns from the previous Haiti course, which consisted of a translucent plastic sheet draped over a PVC frame. The proper level of humidity was maintained through the use of humidifiers, kept running constantly for the entirety of the curing process. While each of the two kilns warmed up and reached optimal humidity, I created the concrete mixtures. For each of the additives, I had two trials: the first with the new additive compromising 25% of the typical aggregate quantity, and the second with the new additive compromising 50%.

For each of these trials, each of the materials was hand-mixed into a batch that produced three concrete units. The wet concrete was then poured into wooden molds, and left inside the kiln until the concrete had cured enough to allow for the removal of the molds. This process was repeated a total of seven times: once for each additive at 25%, once for each at 50%, and once as a control trial.

After the optimal 28 days for curing in humidified conditions, the blocks were removed from the kilns and allowed to dry out for 12 hours. They
were then transported to the basement of the College of Architecture and Planning for testing on the in-house concrete testing machine.

Each block was compressed until structural failure, when the concrete either cracks or crumbles. The testing mechanism recorded the ultimate stress pressure, so that after failing, the ultimate pressure could still be read. For each trial (e.g., plastic regrind at 25%), the final stress was recorded, and for comparison purposes, the results of each trial were averaged.

After all tests had been completed*, the plastic regrind at 25% outperformed the control composition by nearly 150%, failing after 1,333.7 psi, while the control failed at 713.4 psi. The recycled rubber also technically outperformed the control block, but only by a meager 1% (failing after 717.3 psi), so in reality, it would be more accurate to say that it performed equally to the control. The paper was the weakest of the three additives, holding up only to 363.7 psi at a 25% replacement, only 50% of the control.

However, even though the rubber crumb block did not withstand the most pressure, I believe that it has the most potential of the blocks for future study and real-world application. While the other blocks either failed and split into large chunks or crushed into rubble, the rubber blocks at both the 25% and 50% replacement cracked and—surprisingly—remained intact. After observing this pattern, I wonder if this characteristic might not be more significant than the block's strength: the rubber strands, in accordance with their properties, held the concrete together rather than falling apart. In a disaster situation, if the concrete fails but is self-contained, then occupants may have enough time to escape before the building collapses completely. This possibility, to control the manner in which a structure fails, may ultimately be more vital than simply the strength of the material.

After having completed this research project, I intend to encourage further scientific study of both recycled plastic and rubber crumb as concrete additives: both successfully withstood higher pressures than the control concrete samples, and one (rubber crumb) may control its own manner of failure. Through either of these, architects and engineers may have the power to save thousands of lives every year; and no designer could ask for a more successful solution.

*All presentation boards/documentation and results spreadsheets are available digitally in the enclosed disk.
Works Cited


