Alternate Reinforcement for Structural Concrete

Barrett Lowe
Cal Poly San Luis Obispo
San Luis Obispo, California

Concrete has been utilized on construction projects for thousands of years, ranging from the Pyramids to the foundation your home is built on. Innovated upon, concrete and its properties have changed over the years, one of the greatest being the discovery of tensile reinforcement. Rebar, commonly known as reinforcing steel or reinforcement bars, have been used in the construction industry for decades. Ranging in size and application, rebar's unmatched tensile strength and anti-corrosive properties make it the champion of reinforcing structural concrete. Though the advancement in technology has created a new era where other materials may take its place. Attempting to utilize other materials that are lighter but acceptable strong, I wanted to evaluate alternatives of readily available materials that could take over rebar's place in the construction industry.

Keywords: Rebar, Reinforcing bars, concrete, tensile strength

Introduction

How the Project Came About?

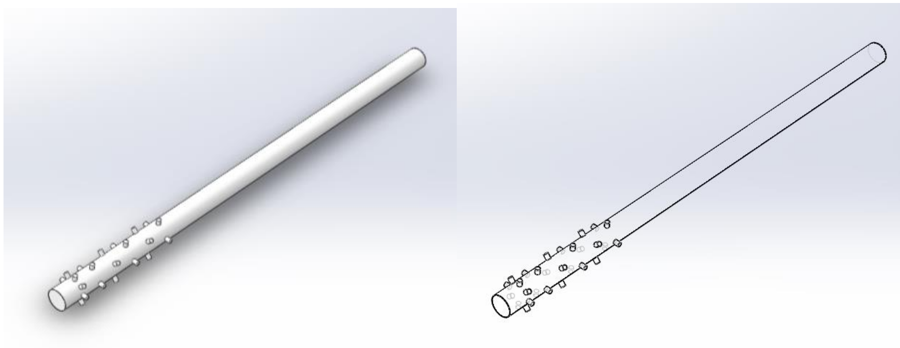
Over the past two summers I've interned for Whiting-Turner Contracting Company, working closely with Pacific Structures and Malcolm Drilling Co. as they were our subcontractors. Throughout that time the use of rebar and several different concrete applications was utilized. Many people know the use of rebar, which is to mitigate and reinforce, due to the lack of tensile strength properties that concrete has, but several other aspects of rebar make it a challenge to use.

One of the main problems I saw with rebar was the weight and how shipping and storing was a challenge on a small and ever-changing site. Additionally rebar is rather dangerous to ship due to its weight and standardized shipping methods that the industry has put into place. For example shipping standard steel rebar on a truck bed must be stacked using wooden inserts to split each level of the whole pile and then tied down with straps. In most cases this works perfectly to get the rebar to the site without any complications. But one story I was told by a foreman was where human error caused a shift of the material during a braking situation and ended up going through the back of the truck cab, killing the driver. This story brought up the idea of trying to find an alternate, but still as strong a material that can be used in lieu of the standard steel rebar reinforcement.

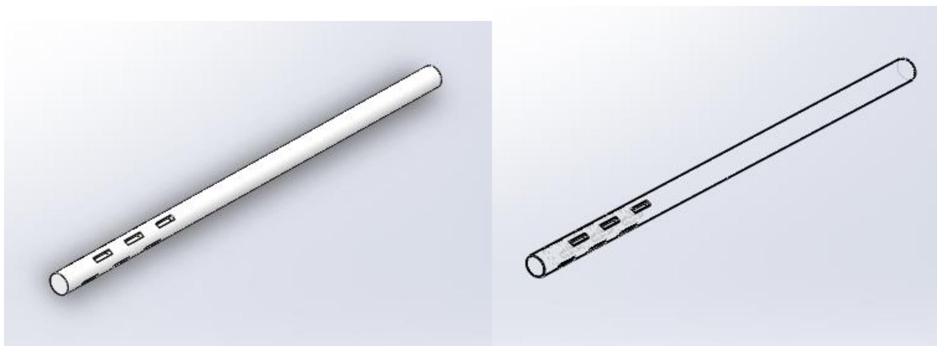
Discussion

Criteria for Production of Reinforcement

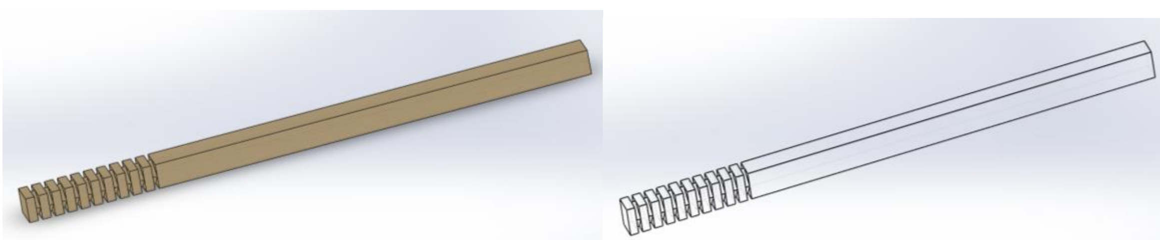
When evaluating the criteria for alternate reinforcement materials and/or embedment shapes, I wanted to follow a baseline that would work across all materials that I tested and for future material testing. The three criteria chosen for my tests and possibly if more testing wanted to be done are: lighter than standard steel reinforcing bars, readily available, and easily manipulated. This criteria checklist was chosen due to the observation that I saw that were issues when working with standard reinforcing bars. Additionally, the point of readily available has to do with an easily obtainable item that a layman could utilize.



PVC with Exterior Nodules (PVC Ext)



PVC with Shelled out Voids (PVC Int)



Standard 2x2 Pine with Cut Sections

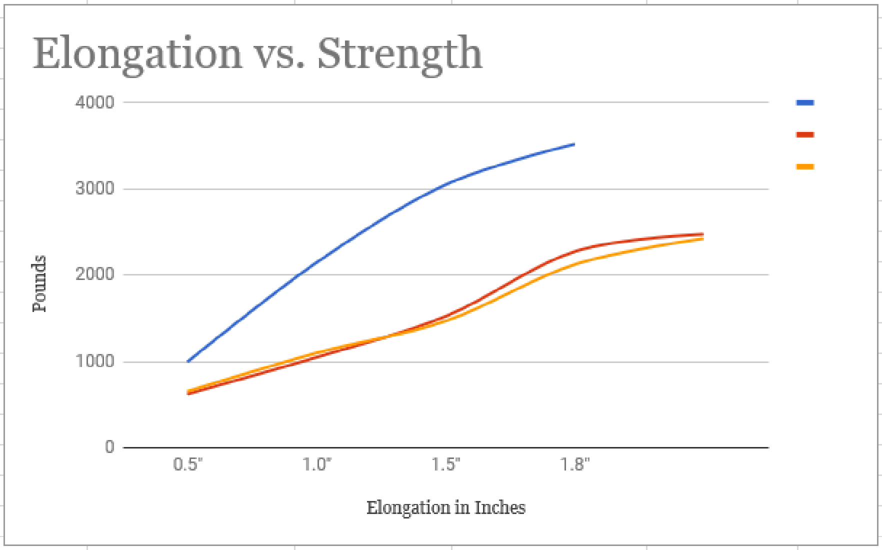
As illustrated from the pictures above, the designs are rather simple, but do not follow the standard ribbed shape that rebar has now. Adhering to the three criteria stated, materials chosen of PVC and wood were used by sourcing from local hardware stores. In addition, the shapes the material were different from the standard ribbed features that steel rebar has. With limited resources and capital, production proved to be rather challenging, especially to the fact that these were first time prototypes.

In reference to the wood, industry professionals would obviously say that wood is far inferior to rebar when evaluating tensile strength. Also mold is common when wood gets wet, mitigating all of its strength as a whole. To avoid the molding process we decided to cover the wood reinforcing with a Rhino liner, most commonly used in protection of truck beds. As a single prototype this method is more expensive,however mass production and the use of Rhino liner may actually prove to be cheaper than rebar itself.

Test Results

Although the results proved that the alternate reinforcement materials I chose were significantly less strong outside of concrete, the scalability for future tests with materials with greater tensile strength could yield a result capable of replacing rebar in the construction industry.

Material Stength / Elongation Graph					
Speed of Test Machine		ASTM Standards <0.1"/second			
Pine Wood		**PVC Ext.**		**PVC Int.**	
Elongation	Pounds	Elongation	Pounds	Elongation	Pounds
0.5"	1000	0.5"	625	0.5"	655
1.0"	2150	1.0"	1050	1.0"	1100
1.5"	3050	1.5"	1525	1.5"	1470
BROKE @ 1.8"	3520	2.0""	2275	2.0""	2125
XXX		BROKE @ 2.36"	2475	BROKE @ 2.41"	2425
XXX		XXX		XXX	

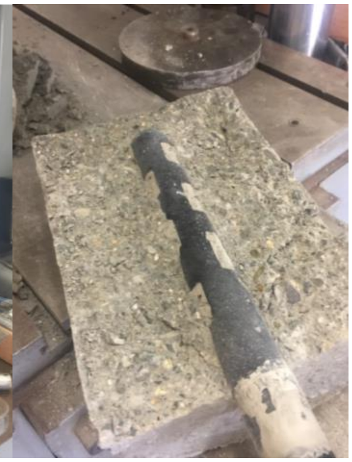


The graph of the curves above display the materials strength vs the extension of the material tested. For testing we, myself and Cal Poly lab technician Vince Pauschek, utilized a Riehle FS-300 Testing Machine. Visible in the picture below, the materials were loaded into the machine and slowly pulled apart until complete failure occured. In reference to the graph, *Elongation* refers the extension of the material, while *Pounds* refers to the force at each distance interval. To keep measurements consistent, intervals of half an inch were used.

After analyzing the data taken it is clear the tensile strength of wood is significantly higher than PVC, as to be expected. Additionally, the data above displays the energy stored in each material prior to failure. The amount of energy stored in the wood per 0.5" was noticeably higher in all cases. This wasn't taken into account during the hypothesis stage, but definitely should be taken into account for future reinforcement testing to evaluate areas that this reinforcement could be used, especially in high seismically active zones.

Lastly, revealed during testing, it was proven that all the materials tested were too weak in tension. In all cases the embedment shapes of each reinforcement method remained completely intact and unmoved. On the other hand, in all cases the materials broke before embedment could even be tested.



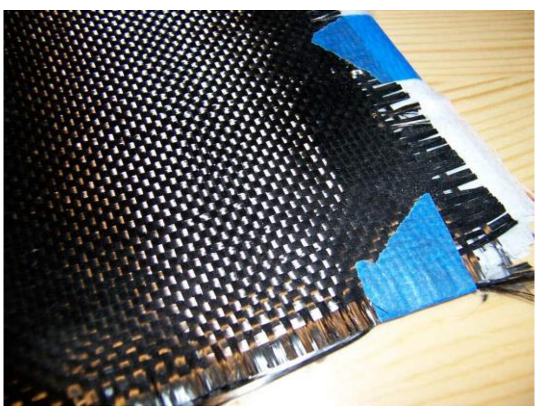



Pine Wood failure point and embedment construction	PVC Int failure point and embedment construction

Conclusion

Lessons Learned

Despite the results of testing done on the materials, it was clear that the unorthodox shapes used in the alternative reinforcement methods held up tremendously. Although the material broke and overall nullified the testing of the embedment, scaling the material to a stronger composite such as carbon fiber while maintaining the same shape could prove to be useful for future testing. Additionally, alternate and untested materials with greater tensile base strength could lead to a true substitute for rebar in the construction industry.



Another aspect that brought up conversation was technological advancements of concrete strength that would lead to the need for less strong reinforcement types. Resources and time didn’t allow for me to test, but utilizing flexible alternatives such as woven carbon fiber or kevlar may be a interesting method for future testing. These methods would still fit the criteria stated, though will definitely be more expensive. In addition, the thin fabric of each would allow for a drastic decrease in shipping costs because on the thin lightweight design.

Though lightweight composites and woods aren’t generally used as reinforcement for concrete, the testing done on these opened the possibility that these less strong alternatives could be used more in temporary construction, my thought being in disaster relief, where receiving the aid is needed as soon as possible. Due to that, the reduction in weight while maintaining a minimum strength standard may prove to be applicable in that situation.