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Reinforcing URM Walls with Fabric

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Abstract— **A preliminary investigation of the use of fabric to reinforce unreinforced masonry (URM) walls in third world countries. Eight common used cloths' rupture strength and Young's Modulus were determined. From those results, they were applied to a hypothetical example to see what amount of area and thickness of a fabric was required to prevent a URM wall from falling down. However, this paper is just the beginning of the concept of reinforcing URM walls in third world countries with fabrics. Therefore, further research is needed to support this concept and have this concept used in real life applications.**

Index Terms—**Fabric, Tensile Test, Reinforcement, URM Walls.**

I. Introduction

Non-engineered structures are very common in third world countries, which means most of the population lives in those types of structures (Okazaki, Pribadi, Kusumastuti, and Saito 2012). These non-engineered structures cause many deaths in these third world countries, especially those countries that are more common to have earthquakes (Okazaki, et. al. 2012). A common non-engineered structure found in third world countries are URM walls.

Using reinforcement in structures improves the overall integrity of the structure. For example, concrete is weak in tension, so steel rebar is used in the concrete to compensate for the weakness (Gupta 2020). Also, steel rebar is used in concrete to allow for warning. Without concrete being reinforced with steel the concrete would suddenly fail, whereas if concrete were reinforced with steel it would not have sudden failure. The steel reinforcement provides more time so sudden failure does not occur and people know to get out of the structure. However, steel is expensive so when possible, it is avoided in construction.

In third world countries the availability and cost of construction affects how structures are built. A common material that is found in every country is fabric. The following explores the possibility of using fabrics to reinforce URM walls. The use of fabric to reinforce URM walls would be a difficult concept to embrace in first world countries where construction materials are more widely available, and the cost is reasonable. So, this paper will explore just the concept of reinforcing URM walls in third world countries.

The use of fabric or similar materials in the construction industry is not that extravagant of a concept. For example, the use of carbon fiber reinforced polymer (CFRP) (Teng, Chen, Smith, and Lam 2001), geotextile (Malvar, Crawford, and Morrill 2007), high-performance textile-reinforced concrete (Curbach and Jesse 1999) and other similar products have been used in the construction industry. Also there have been various test and researched performed on those materials (Mansourikia and Hoback, 2014) and (Mansourikia and Hoback, 2015).

The purpose of this research is to explore the possibility of using fabric to reinforce URM walls in third world countries, so the wall does not fall down in seismic events.

II. Testing of Fabrics

Tensile tests were performed on common used cloths to determine its stress-strain curve, rupture strength, and Young's Modulus. The following cloths where tested: T-shirt, towel, shorts, bed sheets, dust rag, socks, jeans, and workout clothes. The quality of all these cloths were mostly similar. The wear of the cloths just came from daily use. However, all the cloths still had their full structural integrity, had no massive holes, had no large portion stained or discolored, and did not have a lot of fraying.

The procedures performed for the tensile tests were: (1) cutting a piece of fabric with dimensions of 5 inches high by 1.3125 inches wide (2) the specimen was necked about 50% of the width of the fabric (3) a caliper was used to measure the thickness of the fabric (4) the specimen was placed in the clamps of the Instron 8511 (Instron) (5) the Instron was powered on and the tensile test was performed. Figure 1 shows a specimen in the clamps of the Instron before the tensile test began. If the specimen tore near or at the clamps that data was not taken into consideration for the results of this paper. If the specimen did not tear during the tensile tests the strength when the loading ended was determined not the rupture strength.

The Instron collected the force and displacement data during the tensile tests. From the force and displacement data a stress-strain curve where graphed. Since the Instron was collecting the data, the data would oscillate for some of the fabric tested. Therefore, a moving average was created to smooth out the data points. Figure 2 shows a sample stress-strain curve for a specimen a of the dust rag. Also Figure 2 shows the Young's Modulus which is defined as the slope of the linear portion of the graph before the fabric ruptured or the loading stopped. In Figure 2 the black line and black triangle represents the Young's Modulus for this research.

Figure 1. Specimen in Clamps

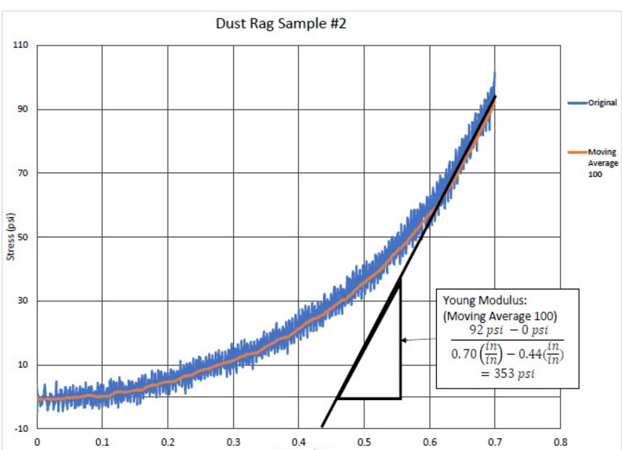

Figure 2. Stress-Strain Curve of Dust Rag

Table 1 shows the average rupture strengths of the fabrics. However, the T-shirt, socks, and workout clothes specimen are not included in Table 1 because when tested none of those fabric tore during the tensile test. Therefore, another type of test was performed on the T-shirt specimens to make it rupture. This procedure was like the one stated above however the Instron was set to perform multiple tensile tests (cycles) on the specimen. Also, the length of time the tensile test was performed varied. After trying a different number of cycles and time frames on the T-shirt specimens, the T-shirt did not rupture. During this test on the T-shirt specimen after the first cycle the specimen had a lot of slack, so when it was loaded again the specimen was not aligned with the clamps. This slack could have been a factor why the T-shirt specimen never tore. This test was not performed on the socks or workout clothes. Table 2 shows the average strengths of the fabrics when the loading stopped. The reason the loading stopped was the Instron was set to a specific time to end the test and once the time was reached the test ended.

Table 1. Average Rupture Strength

Fabric	Average Rupture Strength (psi)
Bed Sheets	3,880
Dust Rag	106
Jeans	1,096
Shorts	2,963
Towel	246

*Out of all the shorts specimens tested only one specimen tore in the middle therefore, the value presented is not an average.

Table 2. Average Strength when Loading Stopped

Fabric	Average Strength when Loading Stopped (psi)
Socks	49
T-shirt	397
Workout Clothes	84

*The T-shirt specimen only had one single tensile test performed on it (the rest of the test with the T-shirt specimens had multiple cycles performed on it). Therefore, the value presented is not an average.

Table 3 shows the average Young's Modulus of the fabrics that ruptured. Table 4 shows the average Young's Modulus of the fabrics that did not rupture.

Table 3. Average Young's Modulus when Fabric Ruptured

Fabric	Average Young's Modulus (psi)
Bed Sheets	21,972
Dust Rag	329
Jeans	4,925
Shorts	42,328
Towel	2,728

*Out of all the shorts specimens tested only one specimen tore in the middle therefore, the value presented is not an average.

Table 4. Average Young's Modulus when Fabric did not Rupture

Fabric	Average Young's Modulus (psi)
Socks	134
T-shirt	1,527
Workout Clothes	145

*The T-shirt specimen only had one single tensile test performed on it (the rest of the test with the T-shirt specimens had multiple cycles performed on it). Therefore, the value presented is not an average.

There were concerns with the testing of the fabrics and the results. Since some of the specimens tore near or at the clamps, we still do not know how much the clamps affected the test results of those specimens that tore in the middle. Also, since a caliper was used to measure the thickness of the fabric, there is a possibility the caliper could have squeezed the fabric changing the thickness of the fabric since fabric is not a firm material. Lastly as stated before there were three fabric specimens that did not tear during the test (T-shirt, socks, and workout clothes). This shows the time setup used with the Instron was not able to tear those specimens. Therefore, the rupture strength was not able to be determined and those fabrics were not used in the hypothetical example below about the concept of reinforcing URM walls in third world countries with fabrics.

III. Using Fabrics For Reinforcement

After the tensile test were performed on the fabrics, the results discussed above were related to the concept of reinforcing URM walls in third world countries with fabrics. This will be done by using a hypothetical example. There will be a URM wall with dimensions of 8 X 8 X (1/3) ft. The reason the wall's width is (1/3) feet or 4 inches, this width is more commonly found in third world countries. The wall will be constructed from hollow concrete blocks with dimensions of 290 X 147 X 140 mm (0.95 X 0.48 X 0.46 ft). This type of hollow concrete block was used in the reference material for this paper (Mansourikia and Hoback 2015). The density of the concrete blocks will be 150 lb/ft^3. Half of the URM wall will fall over for this example. Therefore, for this hypothetical example the amount of area and thickness of fabric required to hold up half the URM wall's weight was determined. Since half of the URM wall falls over and the wall is made of hollow concrete blocks the weight that the fabric would need to hold would be 802.5 lb (0.8025 kips). The assumed eccentricity was 1 inch because a safety factor of 2 inches was used and the center of gravity is half of the top deflection therefore half of the safety factor makes the eccentricity 1 inch. Also, for this hypothetical example, the wall will move perpendicular to the movement of the building.

From the average rupture strength of the fabrics presented in Table 1, Table 5 shows the amount of area required of fabric to hold up the hypothetical URM wall. Table 6 shows the thickness required of fabric to hold up the hypothetical URM wall if the fabric was spread across the 8-foot wall, since the areas presented in Table 5 would just be concentrated at a single point of the wall. The thickness presented in Table 6 assumes a single layer of fabric, not fabrics stacked on top of each other. Comparing these thicknesses in Table 6 to the thickness of each fabric tested shows that each fabric's thickness is greater than the required thickness calculated for that fabric. This means a single piece of fabric across the wall would be adequate to hold up the wall. However, these results were not verified since this was a hypothetical example and was not tested in a lab

Table 5. Area of Fabric Required to Hold Up Wall

Fabric	Area Required (in^2)
Bed Sheets	0.052
Dust Rag	1.89
Jeans	0.18
Shorts	0.067
Towel	0.81

Table 6. Thickness of Fabric Required to Hold Up Wall

Fabric	Thickness Required (in)
Bed Sheets	5.42×10^{-4}
Dust Rag	2.00×10^{-2}
Jeans	1.88×10^{-3}
Shorts	6.98×10^{-4}
Towel	8.43×10^{-3}

This research mainly focuses on the ability of fabrics to hold up URM walls from falling over in seismic events. However, fabrics could be used for decreasing deflections in URM walls or change the types of cracks that appear.

M.T. Mansourikia and A. S. Hoback performed testing of reinforcing walls with CFRP laminate and fabric during seismic loading and compared crack patterns between the walls reinforced and walls not reinforced. (Mansourikia and Hoback 2015). The results show that reinforcing the wall with CFRP laminate and fabric, most of the crack types changed from single diagonal cracks when unreinforced to spread cracks when reinforced. (Mansourikia and Hoback 2015). Also, M.T Mansourikia and A. S. Hoback performed testing of reinforcing walls with geotextiles and CFRP specimens during seismic loading and looked for how it impacted the deflections of the wall (Mansourikia and Hoback 2014). The results show that reinforcing the wall with geotextiles and CFRP decreases the deflections of the wall compared to the walls that were not reinforced (Mansourikia and Hoback 2014).

IV. Conclusion

The use of fabric as reinforcement of URM walls in third world countries needs further investigation to be used in a real life situation However, this is a steppingstone in this concept of reinforcing URM walls in third world countries with fabrics to be more known.

To continue this research on URM walls being reinforced with fabric, there are further steps that should be taken. One is testing the results of the thickness of fabric required, presented in Table 6, to hold up the wall presented in the example to see if the results are accurate. Also, repeating both tests performed by M.T. Mansourikia and A. S. Hoback related to cracks and deflections in URM walls, however using fabrics presented in this research. Another test that could be performed is studying the relationship between adhesives and fabric. This would entail testing different adhesives with fabrics to determine the effects it has on the properties of the fabric. A theory of adding the rupture strengths of concrete and fabrics together should be investigated more because concrete has a low rupture strength in tension and fabric cannot be compressed to get the fabric to rupture to determine its strength. Therefore, simply adding the rupture strengths of concrete in compression and fabric in tension is not a possible theory since the rupture strengths are determined in different methods. Another item that could be done to enhance this research is having fabrics tested that have different wear conditions because fabrics all over the world will differ from being brand new fabrics to raggedy fabrics that have holes and stains all over them. This process would entail creating a rating scale for the quality of cloths used in the experiment. A draft of a rating scale for the quality of cloths was created for this research. This scale had a rating between 1 and 5. The rating of 1 was cloths that had small holes, a little staining and discoloring, and did not have a lot of fraying. The rating of 5 was cloths with a lot of holes (the material is almost completely see-through) and there is a lot of staining and discoloring. This rating scale was not investigated and incorporated more in this research because most of the cloths would have had a 1 rating for the quality. Lastly as stated, there were three specimens tested that did not tear (T-shirt, socks, and workout clothes). The reason those fabrics did not tear was concluded to be how the Instron was setup in terms of the length of the tensile test. The Instron did not have the loading power to tear these specimens in a single tensile test or multiple tests in the time setup used. Therefore, using a longer time period with the Instron for the tensile test would be needed. If these next steps are taken it will show more if reinforcing URM walls in third world countries with fabrics can be a possibility in the future.

On an aside, according to the United States Environmental Protection Agency (EPA) there is a ton of clothes and similar materials that get thrown away every year in the United States of America (EPA 2020). According to the EPA in 2018 only about 1,690 US tons of clothes and footwear were recycled, and 9,070 US tons of clothes and footwear were thrown into landfills (EPA 2020). Also, according to the EPA in 2018 only about 240 US tons of towels, sheets and pillowcases were recycled, and 1,030 US tons of towels, sheets and pillowcases were thrown into landfills (EPA 2020). If that much fabric is going into our landfills yearly, there should be a program created to help collect these discarded fabrics because one of these days these discarded fabrics could be used to reinforce a URM wall in a third world country.

V. Acknowledgement

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