Utilizing Different Types of Synthetic Fabrics as a Cement Reinforcement for Concrete Tile Roofing

Blessed Isaac C. Conde and Daniel Jerlan S. Coladilla
La Salle Green Hills, blessedisaaccconde, danieljerlan@gmail.com

Abstract - **This study aims to alleviate the problem of concrete deterioration by introducing a material to be used as a cement reinforcement to concrete roof tiles that will decrease its water absorption percentage, without decreasing its flexural tensile strength score. Five sample groups consisting of four experimental and one control group of downgraded (modified size) flat concrete roof tiles were used for experimentation. The experimental groups were reinforced with equal amounts (15 grams) of acrylic, nylon, polyester, or rayon fabric shreds, respectively. Both experimental and control groups were uniformly treated with water to cement and cement to sand optimal volume ratio. Using the *p*-value method on Kruskal-Wallis *H*-test ($\alpha = 0.01$, $N = 10$, $df = 4$) in both tests, results show that each sample group distribution had no significant difference among the other groups in terms of both test scores. Despite both *p*-values ($p \approx 0.081$) falling to the null hypothesis non-rejection region of $p \geq 0.01$, it may still be observed that all experimental groups scored lower flexural tensile strength and water absorption percentage scores. The results showed the potential of adding nylon to reduce the water absorption of concrete. Nylon-added samples have the least mean percentage of water absorbed and mean flexural tensile strength score while the control group had the highest mean scores on both tests. Consequently, adding synthetic fabrics lessened water absorption and flexural tensile strength scores. It is recommended to consider other properties under the Roofing Tile Association of Australia (RTAA) and to explore if increasing the sample size will show significant differences in the scores across all sample groups.**

Index Terms - concrete roof tiles; flexural tensile strength; synthetic fabrics; water absorption

INTRODUCTION

Roof tiling design has been present since the early 3rd millennium B.C. in Lerna, Greece [1], which replaced the primitive thatched roofing design [2]. These roof tiles are made to primarily protect people's houses from strong heavy rains, hail, and other weather disturbances. Roof tiles are commonly made of clay, cement, and in the modern era, plastic; even though clay tiles are more durable (lasts over 100 years) than cement tiles (last between 30 to 50 years), clay tiles costs 30% more that how much cement tiles costs [3]; therefore, it is a more common purchase for most consumers.

The textile industry produces thousands of tons of fabric wastes daily. Fifteen percent of fabrics intended for clothing ends up on the floor and this waste rate has been tolerated industry-wide for decades, while eighty-five percent of the waste only go to landfills but ninety-five percent of those are being recycled [4]. Sixty percent of clothes worldwide are made of forms of plastic known as synthetic fibers, such as polyester, nylon, and acrylic [5]. The said fibers are known to contribute to ocean plastic pollution. These microplastics are toxic to wildlife, as they can be ingested by marine life and be accumulated in the food chain; around 73% of fish in the Northwest Atlantic had microplastics in their stomachs ([6], as cited in Reference [5]). In the Philippine setting, alone, 29% of clothes thrown away have only been used once [7], contributing even more to fabric waste and pollution.

There are already numerous studies about the fortification of plastic materials to cement like the article made by Chu (2017) [8]. Also, these plastic-fortified cements are being used to manufacture concrete roof tiles like the study of Abutin et al. (2018) [9]. This research utilizes different kinds of fabric waste strips in fortifying roof tiles since these are made of both cellulosic fibers and plastic materials that are blended to create a strong fabric [10], both strong flexural properties may have a direct effect to the concrete roof tiles when it is used as a cement reinforcement. Since some of the synthetic fabrics are made to repel water, it may also repel water if the material is used as a cement reinforcement to concrete roof tiles which is essential to a roof tile to function with its best properties.

The immediate response of the homeowners is to replace the common metallic roof with either concrete or terra-cotta roof tiles when experiencing metallic roofing corrosion but due time, functional problems may still be observed using these materials. Although terra-cotta roofing is longer-lasting than concrete roofing, concrete roofing is still a popular choice because of its cheaper cost. One solution to these problems is to reinforce plastic materials to concrete roof tiles [9]. This may reduce the water permeability of concrete but the downside is the decrease of its flexural tensile strength. Due to the abundance of synthetic fabrics textile waste, which may be plastic and cotton blend materials, the researchers proposed to modify the materials used by Abutin et al. (2018).

Roofing Tile Association of Australia (RTAA)

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introduced 7 properties for testing concrete roof tiles [11]; due to time and budgetary constraints of the researchers, only 2 properties were properties were tested, namely water absorption and permeability (water absorption test) and durability (flexural tensile strength test). Two samples per sample group of every test were used. There is a specific test for the resistance to salt attack but the researchers were not able to perform it due to the lack of facilities.

METHOD

Pre-experimental static group research design was used to compare one control group to four experimental groups in testing the flexural tensile strength. This design was indicated by the only observation obtained from the testing, which was after the samples break due to the test. Meanwhile, a nonequivalent control group design with multiple experimental groups was used for the water absorption testing. Ratio level raw data are collected for both tests. Due to the lack of samples per sample group, Kruskal-Wallis *H* test was used as non-parametric test.

The study was conducted at La Salle Green Hills (LSGH) in Mandaluyong City, Metro Manila. The researchers made use of the school's Senior High School Science Laboratory, with the permission of the school authorities for the researchers' Practical Research course. Acrylic, nylon, polyester, and rayon were the four types of synthetic fabrics used to reinforce each experimental group, respectively. Table I shows the concoction of downgraded samples. Samples were downgraded by not having the concrete roof tile standard size; this was due to the lack of equipment in the institution to test the flexural tensile strength of samples with the standard roof tile size Optimal water to sand and sand to cement volume ratio is used [12]. The mass of synthetic fabrics added to each sample was decided by the researchers. The properties of each fabric when used as an additional aggregate should only be tested; therefore, the decided mass may not affect the properties of the synthetic fabrics used.

TABLE I
CONCOCTION OF SAMPLES

Sample Groups	Samples	Water (l)	Sand (l)	Cement (l)	Synthetic Fabrics(g)
1	Control 1	0.60	1.20	1.80	0
	Control 2	0.60	1.20	1.80	0
2	Acrylic 1	0.60	1.20	1.80	15
	Acrylic 2	0.60	1.20	1.80	15
3	Nylon 1	0.60	1.20	1.80	15
	Nylon 2	0.60	1.20	1.80	15
4	Polyester 1	0.60	1.20	1.80	15
	Polyester 2	0.60	1.20	1.80	15
5	Rayon 1	0.60	1.20	1.80	15
	Rayon 2	0.60	1.20	1.80	15

Figure I illustrates the flexural tensile strength setup. The flexural tensile strength scores were computed using Equation (1); where *F* is the load (force) at fracture point (N), *L* is the length of the support span, *b* is the width of the sample, and *d* is its thickness [13]. Even though the laboratory can only weigh mass, the weight can still be calculated with the use of Isaac Newton's formula for weight (*F* in Newtons, N), as shown in Equation (2), where *m* is the mass (in kg) hang between the samples until rupture.

$$f_b = 3FL/(2bd^2) \quad (1)$$
$$F \approx m\ (9.8\ \text{m/s}^2) \quad (2)$$

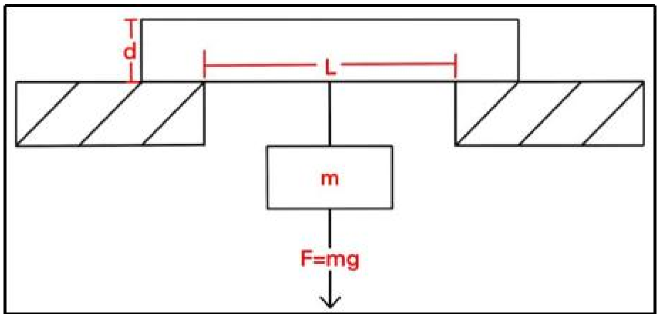


FIGURE I
DIAGRAM OF THE THREE-POINT BENDING FLEXURAL TENSILE STRENGTH SET-UP

On the other hand, for the water absorption testing, a 24-hour soaking test was administered. Samples were washed with distilled water to remove finer particles and dust, and then put in an oven for one hour to remove the moisture. Samples were weighed after being soaked in distilled water for 24 hours, was wiped with cloth to avoid weighing excess water, and was weighed again for its wet mass. Equation (3) was used for the percent water absorption formula, where *A* is the sample's wet mass and *B* is its dry mass [14].

$$\%\text{Absorption} = (A - B) \times 100 / B \quad (3)$$

RESULTS

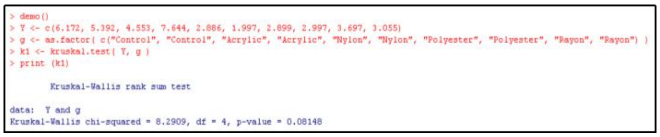
Table II presents the tabulation of raw and computed data for the water absorption test of concrete paving blocks reinforced with different types of synthetic fabrics, respectively using the percent absorption formula shown in Equation (3). A huge factor that might have contributed to the permeability of sample groups with high percent of water absorbed was the fabric materials reinforced respectively. Other types of synthetic fabrics used were stretchable; therefore, allowing water to be absorbed by the fabrics and the concrete samples, concomitantly.

TABLE II
TABULATION OF RAW (MASSES IN GRAMS) AND COMPUTED (PERCENTAGES) DATA OF WATER ABSORPTION TEST

Sample Groups	Samples	Dry Mass (g)	Wet Mass (g)	Water Absorbed (%)
1	Control 1	382.4	406.0	6.127
	Control 2	350.5	369.4	5.392
2	Acrylic 1	450.3	470.8	4.553
	Acrylic 2	380.7	409.8	7.644
3	Nylon 1	516.2	531.1	2.886
	Nylon 2	505.8	515.8	1.997
4	Polyester 1	410.5	422.4	2.899

	Polyester 2	470.4	484.5	2.997
5	Rayon 1	468.0	485.3	3.697
	Rayon 2	471.3	485.7	3.055

The nylon-reinforced concrete roof tiles showed less permeability to water compared to other sample groups as shown in Figure II. This may have been caused by a fabric's physical property of having a hydrophobic plastic surface [15]. Unlike any other synthetic fabrics used, the results show the ability of nylon to be less permeable to water even when reinforced to concrete; consequently, it supports the results of Abutin et al. (2018), which mentions that plastic materials may help concrete reduce its water absorption percentage when used as a reinforcement [9]. Using the program language *R*, the Kruskal-Wallis *H* test results may infer that there is not enough evidence to support the claim that "At 0.01 level of significance, at least 1 of the 5 sample groups differ from the rest in terms of median water absorption percentage."



```
> demo()
> Y <- c(6.172, 5.392, 4.553, 7.644, 2.886, 1.997, 2.899, 2.997, 3.697, 3.055)
> g <- as.factor( c("Control", "Control", "Acrylic", "Acrylic", "Nylon", "Nylon", "Polyester", "Polyester", "Rayon", "Rayon") )
> k1 <- kruskal.test( Y, g )
> print (k1)

        Kruskal-Wallis rank sum test

data:  Y and g
Kruskal-Wallis chi-squared = 8.2909, df = 4, p-value = 0.08148
```

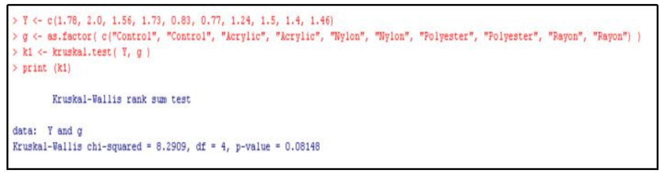
FIGURE II
SCREENSHOT OF THE R LANGUAGE CODE COMPARING THE MEDIAN PERCENT WATER ABSORPTION OF SAMPLE GROUPS

Table III tabulates the raw and calculated data used for the flexural tensile strength score wherein each sample group, used 2 samples. Focusing on nylon-reinforced concrete samples, the table shows that the nylon-reinforced concrete roof tiles tend to have the least flexural tensile strength among all the concrete implying that the decrease of flexural tensile strength will consequently decrease the percent water absorption as shown in both tests, tabulated in Tables II and III.

TABLE III
TABULATION OF RAW (MASSES AND MEASUREMENTS) AND COMPUTED (N AND KPA) DATA OF FLEXURAL TENSILE STRENGTH TEST

Sample Groups	Samples	Support Length (mm)	Block Width (mm)	Block Height (mm)	Weight Load at Rupture (N)	Flexural Tensile Strength (kPa)
1	Control 1	114.3	105.0	15.0	245	1.78
	Control 2	114.3	105.0	15.0	274	2.0
2	Acrylic 1	114.3	105.0	15.0	345.45	1.56
	Acrylic 2	114.3	105.0	15.0	382	1.73
3	Nylon 1	114.3	105.0	15.0	147	0.83
	Nylon 2	114.3	105.0	15.0	137	0.77
4	Polyester 1	114.3	105.0	15.0	304	1.24
	Polyester 2	114.3	105.0	15.0	368.5	1.50
5	Rayon 1	114.3	105.0	15.0	308.7	1.40
	Rayon 2	114.3	105.0	15.0	323	1.46

Same process of hypothesis testing was shown in Figure III. Using the program language *R*, the Kruskal-Wallis *H* test results may infer that there is not enough evidence to support the claim that "At 0.01 level of significance, at least 1 of the 5 sample groups differ from the rest in terms of median flexural tensile strength score."



```
> Y <- c(1.78, 2.0, 1.56, 1.73, 0.83, 0.77, 1.24, 1.5, 1.4, 1.46)
> g <- as.factor( c("Control", "Control", "Acrylic", "Acrylic", "Nylon", "Nylon", "Polyester", "Polyester", "Rayon", "Rayon") )
> k1 <- kruskal.test( Y, g )
> print (k1)

        Kruskal-Wallis rank sum test

data:  Y and g
Kruskal-Wallis chi-squared = 8.2909, df = 4, p-value = 0.08148
```

FIGURE III
SCREENSHOT OF THE R LANGUAGE CODE COMPARING THE MEDIAN FLEXURAL TENSILE STRENGTH SCORE OF SAMPLE GROUPS

DISCUSSION

This study aims to introduce a new material that can be used to fortify concrete and will improve its flexural tensile strength while decreasing its water absorption percentage. The study finds no significant difference among the 5 samples groups in terms of water absorption percentage. Meanwhile, it can be observed that even though at 0.01 level of significance, all the 5 populations of the concrete blocks have the same distribution in terms of flexural tensile strength and water absorption percentage, the data collected showed outliers that can be considered significant without using statistical tools.

The study supported the results found by Abutin, Arkuino, Romano, & Topacio (2018) wherein aggregating concrete with plastic materials will reduce the water absorption percentage [9]. On the other hand, the result of several studies like the study of Hidayat, Irpan & Siauwantara (2014), also shows the same concept wherein as a concrete increases the amount of its aggregate, the tensile strength will decrease [16].

Though the researchers claim at first that concrete strengthens by fortifying it with synthetic fabrics which have both the properties of cellulosic and plastic materials, the results does not show an increase of flexural tensile strength to any experimental groups compared to the control group. Meanwhile, the claim of reducing the water absorption percentage of the experimental concrete groups were shown in the results but has no significant difference according to statistics.

The most important discoveries in the study lies in the fact that it supports the results of the previous research conducted. It is notable to mention that the discoveries about the variables will greatly affect the increase or decrease of the quality of concrete in terms of flexural tensile strength and water absorption test.

The study has many flaws that other researchers should take into consideration in replicating or validating the results of their future study. Starting with the prototype, the researchers recommend not downgrading or modifying the size of the prototype since the actual standard roofing tile sizes are being used in the practical setting. The researchers recommend moulding an actual concrete shaped for concrete roof tiles. Also in moulding the specimens, it is recommended to shake the cement until all of the bubbles that will create holes goes out of the surface or the inside.

It would also be better and more reliable if the sample size of each sample group will reach more than 5 based on the Kruskal-Wallis test. This would make use of the chi-square distribution to yield a determinate H-statistic or *p*-value, due to different data inputs per tests. In this case, two different tests show similar *H*-statistic and *p*-value which may indicate that the data is suspicious.

To ensure that getting the dry mass of the specimen are more precise, it is recommended to control the temperature inside the oven to make sure that the moisture inside the concrete evaporates. It is also suggested to add more synthetic fabrics to be compared in the study for more variety. In relation with synthetic fabrics, it is recommended to use the optimal additional aggregate (synthetic fabrics) to cement or water ratio in terms of volume as opposed to putting synthetic fabrics, 15 grams each only for uniformity, which may be a threat to the internal validity of the study.

In adding masses in the flexural tensile strength test, it would be more precise to use a machine to test it. If there is still no access to a machine, adding masses with smaller increments will show a more precise f_b value of the specimen before rupture.

To be more distinct about the synthetic fabrics used in the study, it is recommended to know exactly what percent blends of organic and plastic materials each of the types of synthetic fabrics are made of.

Another variable that needs to be taken into consideration is the increment of adding weights one for a more precise f_b value. Other properties should also be taken into account based on the properties of concrete roof tiles that are established by the RTAA. Two out of 7 properties of roof tiles were only observed in this study. These two properties should not be the basis to generalize other properties of the experimental and control group. The properties of concrete roof tiles based on RTAA are the following: water absorption and permeability, durability, cyclone and high-wind resistance, fire resistance, acoustic performance, thermal performance, and resistance to salt attack.

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AUTHOR INFORMATION

Daniel Jerlan S. Coladilla and **Blessed Isaac C. Conde**, students, Science, Technology, Engineering, and

Mathematics (STEM) Strand, Senior High School Department, La Salle Green Hills, Mandaluyong City.