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Preliminary Examination of the Effects of Time and Flexural Direction on an Anisotropic Geosynthetic Cementitious Composite Mat

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Undergraduate Departmental Honors Thesis

Under the Guidance of:

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Abstract

The significance of this research was to determine the effect the main fabric weave direction and cure time has on the maximum load of 0.34 inch anisotropic Geosynthetic Cementitious Composite Mat sample coupons. Two series of tests were run. The first used a three-point bend test on the material samples with varying cure times to determine the average maximum load associated with each. The second series of testing used followed ASTM D8030/D8030M – 16 for sample preparation and ASTM D8058 – 17 for testing to determine the flexural strength and modulus of elasticity of the test samples with and against the main machine weave pattern. The results indicated no significant difference between the variations of cure times. However, the results did indicate a significant difference between flexural strength of with and against machine weave.

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Introduction

Geosynthetic cementitious composite mat (GCCM) is a recently defined material that consists of a reinforcing fiber matrix, a permeable fabric top surface, and an impermeable PVC bottom layer. The mat is impregnated with a formulated dry concrete mix and is then stored in rolls. After the roll of material is laid, it can be cut into sections with a utility knife and formed to use for different applications. When hydrated, the GCCM begins its curing process and hardens to form a concrete layer. There is a broad range of applications for this GCCM; this includes rapid creation of durable concrete structures, erosion control, external pipe protection, ballast, internal culvert repair and lining, drainage and ditch lining, irrigation collection, as well as slope and berm erosion protection.

Since the material is positioned on top of a prepared natural surface in the cases of erosion control and drainage ditch lining, there is the possibility that stones may heave from surfaces to be proud of the original preparation and remain under the cured GCCM. After a stone becomes prominent of the natural surface, it will press against the GCCM bottom layer. The natural heaving of stones from the subsurface takes time. Additionally, cementitious mixtures have been known to have a positive relationship to strength. Considering this, the focus of this study is to observe the effect curing times has on the tensile strength of the material.

Research Questions

Geosynthetic Cementitious Composite Mats can be used in a variety of different environments and can solve a large array of problems. In order to know whether using a GCCM for a particular application will be appropriate, several questions must be considered such as: what is the peak load the GCCM can stand before initially breaking? What is the peak load after initial break before complete failure? What machine grain orientation will provide the most effective layout of material?

Literature Review

Since anisotropic Geosynthetic Cementitious Composite Mats are still fairly new materials that are being used industrially, the implementation of the material is not fully optimized. Currently, there are projects that are making use of these materials. For example, Cal Poly's Swanton Pacific ranch used the drainage channel to redirect water flows

Figure 1 - Completed installation [1]

resulting from steam engine flushing and storm water flows [1]. Their project implemented a polyester textile reinforced concrete, GCCM, to control the flow of this run off water. By using a GCCM as opposed to previously used methods for erosion control, such as lining a ditch with gravel wash, they effectively solved the water flow problem and ensured no future erosion issues. The layer of GCCM can also be removed much easier than a channel filled with stone in the event that the channel is to be removed.

Irrigation projects represent another large area of interest in implementing GCCMs. With many systems being in place for decades, they almost inevitably need to be repaired. When the concrete basins of the irrigation systems begin to crack,

Figure 2 - Repaired sides and bottom of basin [2]

instead of breaking out the entire concrete structure, a GCCM can simply be applied over the existing structure [2]. This strategy is not only cost effective, but it also saves time. The GCCM will allow running water to flow across without getting penetrated because of it's polymer lining.

Another type of project where the use of a GCCM can be beneficial is metal pipe culvert lining. When a metal culvert pipe reaches a point to which it needs to be replaced or relined, a GCCM can be considered as a cost effective and timely fix. Although the expected life of the GCCM is only 5-10 years compared to 40 years for a complete replacement, the cost would only be 10% and can be set up in less than one day [3]. The effectiveness of the GCCM repair would be just as good if not better than a full replacement when weighing in the cost and time spent on the repairs.

Figure 3- Installing the GCCM panels [3]

Part 1

Method

The GCCM had a thickness of 0.34 inches sectioned into pieces 9.5 inches long and 4.7 inches wide. Eleven samples with the knit machine grain going lengthwise and eleven widthwise were made.

The testing used a three point flexural test. The curing times tested were 24 hours, 1 week, 2 weeks, and 4 weeks. The SATEC testing machine was used to ensure consistent and accurate forces were applied to each of the samples for the duration of the study. The two bottom supports of the SATEC machine were set 7 inches apart with the loading edge on top placed in the center of the span. The peak load was found by applying a constant force in the center point of the samples and recorded for analysis.

Figure 4- 3 Point-bend test being performed on SATEC

Results

The results of the tests are seen in Table 1. This table shows the mean, standard deviation and sample size for each combination group.

	Lengthwise, x-bar (s)	Widthwise, x-bar (s)
7 day	59.75 (9.32), n = 4	35.50 (4.65), n = 4
14 day	63.75 (9.18), n = 4	37.50 (3.70), n = 4
28 day	59.00 (5.57), n = 3	32.00 (1.73), n = 3

It was first determined that there was no interaction term (p = 0.9185). Then using a basic A×B factorial ANOVA without an interaction, it was found that there was not a significant difference in outcome by Unit (7 day vs. 14 day vs. 28 day); p=.3216. The absolute value differences by pairwise groups are (means and standard errors with Tukey adjusted p-value):

- 7 day vs. 14 day: 3.00 (3.11); p=0.3470
- 7 day vs. 28 day: 2.13 (3.36); p=0.5345
- 14 day vs. 28 day: 5.13 (3.36); p=0.1441

There was a significant difference in grain (lengthwise vs. widthwise); p<.0001.– Although we know the p-value is the same as above, because there are only two groups in this main effect. The absolute value differences by pairwise groups are (means and standard errors with Tukey adjusted p-value):

- Long vs. Short: 25.73 (2.65); p<0.0001

Discussion

With these results, it is clear that the material reacts differently depending on orientation. The strength is nearly double when breaking perpendicular to the main grain of the fabric compared to breaking parallel. After 7 days of curing, there was no significant change in strength of the material. Further studies need to be performed following the asymmetric standard. The material displayed pseudo ductile properties and achieved the recorded peak loads after the initial break. This may be due to the cement cracking inside the fabric and then accumulating along the break joint reinforcing it. Even after bending the samples well past their peak loads, they still had a considerable rigidity and held the new shape firmly.

Part 2

Method

The Standard Practice for Sample Preparation for GCCM designation: D8030 was used to prepare samples for testing [4]. The average thickness of the samples was 0.34 inches with a width of 2.5 inches and an overall length of 12 inches. Using a 12in X 12in die, the samples were initially cut into 6 over-sized coupons from the main roll of material. These coupons were then transferred into two large tubs to be sandwiched between two permeable pavers and then submerged into water. They were allowed to cure in water for 24 hours. After, the samples were removed from the water and left for an additional 7 days to continue curing. Using a tile wet saw, the final dimensions of the testing samples were cut; 4 samples from each coupon were cut for a total of 24 samples. There were 12 samples with a main grain (group A) running the length and 12 running the width (Group B). These final samples were labeled and set aside for testing.

The Standard Test Method for Determining the Flexural Strength of a GCCM designation: D8058 was attempted but not successful [5].

Results

The original goal of this test, according to the ASTM D8058, was to determine the flexural strength of the GCCM using peak load at the initial break [5]. Also, the modulus of elasticity was to be found using points taken from two points within the linear section of the plot before the initial breaking load. In calculating the two, inferences can be made to about how well the material will withstand a particular application.

Problems occurred when trying to use the SATEC machine to perform the flexural test and record data. There were two main issues that restricted accurate results from being obtained. The first problem being that the SATEC machine has a load cell with a maximum capacity of 50,000 lbs. The samples being used will not withstand more than 50 lbs due to their thin depth and narrow width. This is a problem because the 50,000 lbs load cell is not completely accurate until 4% of this maximum load. Attempting to operate the machine at a threshold of less 0.1% would most likely give inaccurate load readouts because the load cell cannot read that precisely. Also, the software would stop recording load and deflection after exactly 10 seconds of running the test. This was not enough time to find the initial break load or create a substantial linear line of load and deflection leading up to the initial break. Moreover, there was not time to study the pseudo ductility of the material well after the initial break.

Discussion

The first problem of the load cell being too big cannot be overcome even by increasing the sample sizes. The floor accuracy level of 2000 lbs would not be achieved. The only way to get past the problem would be to use a testing machine with a much smaller and more precise load cell that can pick up on lighter loads more accurately. The second problem faced can be overcome because this appears to be a software issue. Instead of having an automatic load failure threshold shutoff set to the machine, a manual option needs to be used so the data will continue to be plotted even past the point of failure. This will ensure the machine will not stop prematurely, and a more continuous study of the properties of the material can be further studied.

Conclusions

Overall, the results from part 1 of testing show a clear relationship between the orientations of the material, despite the inaccuracy of the testing machine because the results were consistent. Stressing the material perpendicular to the main grain of the fabric proves to be stronger than stressing parallel to it. Also, part 1 of testing shows no significance between cure times after 1 week.

Although concrete is known to continually gain strength the longer it has to cure, it was assumed that because the samples were so small in their dimensions, the overall strength of each is also small. The gain in strength over time is not significant enough to show up in these tests.

With concrete being the most extensively used material around the world, it should come as no surprise that even more applications of the material are being discovered today [6]. The implications GCCMs have on industry have only just begun to be discovered and many more should be expected. Continual research is needed to fully understand and properly implement GCCMs.

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