A STATISTICAL ANALYSIS OF SISAL, NYLON AND RUBBER FOR A DRYING LINE.

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Abstract.3

This project investigates the application of different materials used as drying lines. It statistically analyzes three types of ropes: rubber, nylon, and sisal, to identify which of them would be the best for a dry line. The study primarily focuses on the experimental data of the force, displacement, tensile strength and elastic modulus of the rope samples obtained using smart technological devices, to draw a conclusion on which one has the least expansion and the highest tensile strength. The data is collected with modern technological tools such as Pasco testing machine and analyzed using MATLAB and Microsoft Excel. The result of the statistical analysis obtained includes sisal with a tensile strength of $8.46 \times 10^7 Psi$ standard deviation and error of 31.7 ± 15.8, followed by nylon $1.407 \times 10^7 Psi$ and 5.0 ± 2.5, and rubber with $5.32 \times 10^6 Psi$ and 1 ± 0.5, respectively. As sisal tends to have the least expansion with highest tensile strength, a well-designed sisal rope is recommended for dry lines.

Keywords: Sisal, Nylon, Rubber, Drying Line.

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1. Introduction

Ropes are primarily useful in our domestic activities. They are ubiquitous, mostly found inside and or outside of our houses. They come in various forms and sizes, thus, big or small and twisted or braided, and with different materials such as nylon, rubber, sisal, leather, cotton, etc. However, some of these ropes, those typically used for dry lines, lose their capacity for supporting a high load after a short period due to weather conditions, the heavy weight of clothes, etc. They often sag or tear, dropping items hung on them on the ground. This problem translates into making the clothes dirty by bringing them closer to the ground and rendering the ropes useless after a period. Hypothetically, it could be that ropes with high elasticity sag faster than those of low elasticity.

1.1 Background

Sisal

Sisal is a strong natural fiber obtained from the sisal plant called *Agave sisalana*. It offers almost 80% of its strength due to the high proportion of cellulose. It is durable, inelastic, and sturdy, but has low resistance to wear or tear. The application of sisal can be seen in the textile industry: for making cloth. It is also used together with fiberglass to form a composite in the automobile industry. Some carpets used in various homes are all made from sisal. The shipping industry uses sisal ropes to moor small craft. In a research article published by Gupta *et al.*, the tensile strength of sisal was found to be 132.73MPa [1].

Nylon

Nylon is a synthetic polymer consisting of Hexamethylenediamine. It was first made in DuPont Chemicals laboratory, USA, by passing the polymer through solutions to increase its plasticity. Nylon did not have a market base until 1940, when it was first introduced in the production of clothing, especially stockings for women's wear [2]. Fortunately, the increase in demand for these ropes has led to a keen competition between synthetic products and biodegradable products. Most of the ropes produced are usually nylon, rubber, and sisal. Laird Plastic, a renowned plastic company, recorded 82.7MPa as the tensile strength of nylon. Nylon has good elasticity but degrades over time when exposed to the sun. This property causes it to stretch, eventually making it elongated and weak. It is however, durable and has excellent resistance to damage from oil and many chemicals [2].

Rubber

Synthetic rubber is a polymer obtained from a petroleum product and has good elasticity. The natural rubber also exists, derived from a concentrated liquid colloidal suspension called latex found in plants. According to history, ancient inhabitants in Mexico and Central America used rubber to make balls used in a game called Mesoamerican ball game. Later, Germany made the first synthetic rubber during the War World I to be used for automobile tires [3]. After this event, further research was conducted by the Massachusetts Institute of Technology to find the different properties of rubber when combined with various chemicals. Today the USA is the leading producer of synthetic rubber. Rubber has excellent elasticity properties; it is ductile and has a tensile strength of 15-22MPa [3].

1.2 Objectives

1. To experimentally measure and determine the best rope for a dry line using statistical analysis.
2. To learn how statistical techniques fit into the general process of solving engineering problems.

1.3 Problem statement and Research findings

In researching the application of ropes as dry lines, Berekuso, a town in the Eastern Region of Ghana, was used as a case study. Over 20 houses were visited, and some observations were made on the types of ropes used in these houses. The data collected revealed that 90% of the ropes used for dry lines were made of nylon, whereas 4% were made from rubber and 2% from sisal, but not used for dry lines.

Observations

1. 100% of the houses visited use synthetic ropes for dry lines.
2. 40% of these houses have sagged dry lines that left clothes touching the ground.

Selection of ropes for dry line

Based on these observations, the proposed hypothesis was that the sagging of the ropes was due to the heavy weight of wet clothes and high expansibility of the rope material; hence, there could be a superior substitute for dry lines. This hypothesis informed the decision to gather an available sample of ropes for experimentation.

Figure 1. A picture of the three samples: nylon(deep green), rubber(orange), and sisal (white).

2. Methodology

2.1 Design of experiment

The experiment aims to statistically select the best rope material amongst the identified group with low elasticity. A further investigation will be conducted on the best material chosen to determine which braiding style increased the toughness of the rope. The strand of sisal and rubber were twisted to form a rope in the same way as nylon is twisted to ensure uniformity in the rope samples being tested. Again, the three ropes were cut into an equal length, and their diameters were measured.

Collection of data

Using the Pasco machine, a force was applied to each of the materials. The force applied, and displacement (change in length) were recorded. After measuring the original length of each sample, the strain was calculated by dividing the displacement by the original length. The stress was also calculated by dividing the applied force on each rope by its area of the sample.

2.2 Statistical Analysis

Normality test: Before choosing ANOVA or Kruskal-Wallis, a normality test was performed to ascertain whether the data was normally distributed or not. With the help of Graphpad, nonparametric tests such as the D'Agostino & Pearson normality test, the Shapiro-Wilk normality test, and KS normality test [6] were performed to provide analysis that will not rely on assumptions that the data are drawn from a normal distribution.

D'AGNOSTINE & PEARSON NORMALITY TEST		
K2	18.49	12.18
P value	<0.0001	0.0023
Passed normality test (alpha = 0.05)	No	No
P value summary	****	****
SHAPIRO WILK NORMALITY TEST		
W	0.9212	0.953
P value	0.0026	0.0454
Passed normality test (alpha = 0.05)?	No	No
P value summary	**	**
KS NORMALITY TEST		
KS Distance	0.09932	0.07109
P value	>0.1000	>0.1000
Passed normality test (alpha = 0.05)?	Yes	Yes
P-value summary	ns	ns

Table 1. Results on normality test.

From the table above, the D'Agostino & Pearson normality [5] test yielded a p-value (0.0001), which is less than the confidence interval (CI) value (0.05), Shapiro-Wilk normality test also yielded a p-value (0.0026) which is also less than the CI value. Since the p-values are less than the estimated CI value, it implies the data is not normal. Although the KS normality test gave a p-value (0.09932), which is higher than the CI value, the other two tests were enough to ignore the result obtained by the KS test. This difference occurred because KS based its p-value on the most significant discrepancy of the distribution, which is efficient for accessing two samples, and not the three samples.

Performing the Kruskal-Wallis Test (nonparametric);

A nonparametric test was performed using the GraphPad software, and the table below depicts the results obtained.

TABLE ANALYZED	KRUSKAL-WALLIS DATA
Kruskal-Wallis test	
P-value	<0.0001
Exact or approximate P-value?	Approximate
P value summary	****
Do the medians vary signif. (P < 0.05)?	Yes
Number of groups	3
Kruskal-Wallis statistics	115
Data summary	
Number of treatments (columns)	3
Number of values(total)	336

Table 2. Kruskal-Wallis test Results.

The results from the table infer that the mean values of the samples are different, hence different expansibility. Besides, the null hypothesis can be rejected since the p-value in the Kruskal-Wallis test (0.0001) is significantly smaller than the CI value. However, the highest expansibility remains unknown.

Post Hoc Test

To investigate how far the difference of expansibility is, a Post Hoc Test was performed. This test is a stepwise multiple comparisons procedure used to identify sample means that are significantly different from each other. It is used often as a post hoc test whenever a significant difference between three or more sample means has been revealed by an analysis of variance.

Number of families	1				
Number of companies per family	3				
Alpha	0.05				
Dunn's multiple comparisons tests	Mean rank diff	Significant?	Summary	Adjusted P-value	
Sisal vs Nylon	-132.5	Yes	****	<0.0001	A-B
Sisal vs Rubber	-117.8	Yes	****	<0.0001	A-C
Nylon vs Rubber	14.63	No	ns	0.8403	B-C
Test details	Mean rank 1	Mean rank 2	Mean rank diff.	n1	n2
Sisal vs Nylon	100.1	232.5	-132.5	122	122
Sisal vs Rubber	100.1	217.9	-117.8	122	122
Nylon vs Rubber	232.5	217.9	14.63	122	122

Table 3 Post Hoc Test Results

From the table above, when the mean value of sisal was compared to that of nylon, the p-value obtained was 0.0001. This value is smaller than the given CI value, which implies that there is a statistical difference between the two mean values. Hence, those two are not related. Moreover, when the sisal mean value was compared to that of rubber, the p-value was also 0.0001 which is likewise smaller than the CI value. Therefore, proving the statistical difference between the two. However, when nylon was compared with rubber, the p-value was 0.8403 which is higher than our CI value. This result implies that there is no statistical difference between the two. This test shows that statistically, sisal is different from nylon and rubber.

Material science analysis

It is seen that sisal is statistically different from the other materials. With knowledge from material science, we can look at the tensile strength and elastic modulus of the three examples to tell which one has the least expansibility.

3. Results

Sample	Ultimate Tensile Strength (MPsi)	Elastic Modulus (MPa)
Sisal	84.6	3084
Nylon	14.07	516
Rubber	53.2	14.5

Table 4. Ultimate tensile strength and elastic modulus of the three samples.

From the above table, sisal has the highest ultimate tensile strength, which is followed by nylon and after that, rubber. The order is still the same in terms of the elastic modulus. This finding, therefore, implies that sisal is better than nylon in terms of using it as a dry line because it has the least expansibility. Again, we recorded data on the stress obtained at the same strain points using Microsoft Excel

Samples	Sample size	Mean	Median	Variance	Standard deviation	Standard error
Sisal	5	51.78	53.7	992.367	31.501857	15.75092
Nylon	5	9.1	10.8	25.31	5.030904	2.515452
Rubber	5	4.14	4.3	0.988	0.993982	0.496991

Table 5. Table showing significant statistical variables.

Second Statistical Test

After inferring that sisal has the least expansion and, therefore, suitable for making a dry line, it was decided to find out how it can be put together to create a stronger rope. As such, two samples of sisal were made. One was designed by twisting two strands of sisal, and the other was made by putting two strands together side by side. Using the Pasco machine, the tensile strength was tested. As previously described the stress and strain of each were calculated.

Table Analyzed	Unpaired T-test data
Column B vs Column A	Twisted vs Joined
Mann Whitney test	
P value	0.8035
Exact or approximate P-value	Exact
P-value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in columns A, B	2489, 2562
Mann Whitney U	1214
Difference between medians	
Median of Column A	0.08167, n=50

Median of Column B	0.08363, n=50
Difference: Actual	0.001959
Difference: Hodges-Lehmann	0.001954

Table 6 T-test Result.

T-Test

For the two sisal groups, we performed a t-test. Since the data from each sample was independent of each other, an unpaired t-test is appropriate. It was assumed that the mean values of their strain would be the same – the null hypothesis.

After the t-test, the p-value obtained was 0.8035, which is higher than the confidence level, therefore, implying that there is no statistical difference between the two designs. So, either way of designing a rope for a dry line using sisal will still have the same strength, statistically.

4. Conclusion

4.1 Limitation.

The experimental data though revealed sisal to be the toughest material, failed to predict whether sisal remained the best material for dry lines when subjected to different factors, such as heat. Further experiments could have been done to collect and analyze data on sisal when exposed to weather conditions and mechanical strain. Also, the computed values in this paper were slightly higher as compared to literature values, which could be attributed to operational errors while using the Pasco machine. The Pasco machine required thin strands of the rope samples, thus, disallowing the performance of tests on ropes with a large thickness.

4.2 Conclusion and Future Works

To conclude, sisal has the least expansion; hence, it can be suggested as the best rope for making dry lines. Due to the lack of materials, we could not determine the behavior of sisal when exposed to various conditions, for example, higher temperatures and moist conditions. However, it should be noted that, even though we have declared it as the best for making a dry line, we cannot guarantee how durable it may be when exposed to different conditions. As such, we intend to research the performance of sisal in weather conditions in our future works, and we will, in this manner, consider structuring our analysis to discover the quality of sisal when exposed to a few weather conditions.

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6. References

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