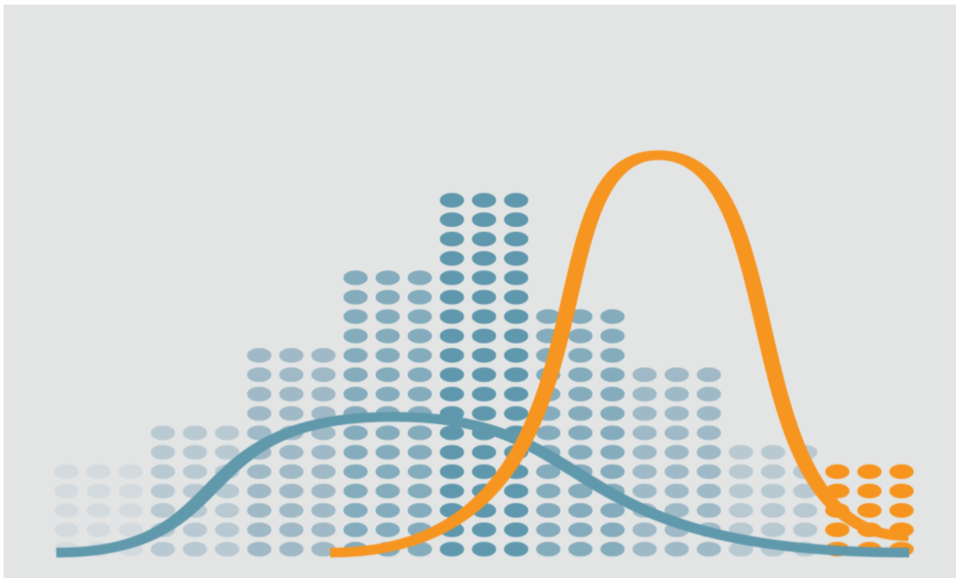
WHICH ROPE FITS BEST FOR DRY LINE?



Statistics for Engineers Final Project Report

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ABSTRACT

This project therefore seeks to analyze three selected sample ropes: rubber, nylon and sisal and justify which of them would be best for a dry line using statistical analysis. It primarily focuses on the force, displacement, tensile strength and elastic modulus of the ropes samples to draw conclusion on which one has the least expansion and the high tensile strength. The data are analyzed with modern technological tools such as Pasco testing machine, laptop and Matlab, Microsoft Excel. The statistics obtained are impressive and they speak for themselves and by contrast, sisal tend to have the least expansion with a high tensile strength.

INTRODUCTION

Ropes play very important in our domestic activities. They are seen all round, both the internal and the external of our house. They are used for hanging of clothes inside room and outside especially, on the dry line. They come in all form of sizes, thus, big or small and twisted or braided, and different materials such as nylon, rubber, sisal, leather, cotton etc. However, some of these ropes sag in after a short period of time due to heavy weight of cloth. It has been of severed that ropes with high elasticity sag in faster than those of low elasticity. Hence, there is a real problem of making the clothes dirty by bringing them closer to the ground and rendering the ropes useless.

Problem Identified:

When we were asked to work on this rope project, our mind could not set on anything at that moment. As such we decided to do a bit of research on the applications of ropes in our daily lives. Using Berekuso as a field of study, we visited there only to have realized that all the houses (20) that we paid a visit use dry lines. Hence, we decided to take a close look at the dry lines to see that types of ropes used and perhaps observe something abnormal there.

OBSERVATIONS

- We saw that 100% of all the 20 houses have their dry lines made of nylon.
- 40% of these houses have their clothes especially, those at the middle of the ropes sunken in or almost touching the ground.
- 10% had their clothes almost all gathered at the middle of the rope, irrespective of the type or number of pegs used.
- 50% had their dry lines was very high yet with clothes gathering at the middle of the dry line.

Now considering all these situations where clothes are touching the ground or gathering in the middle of the ropes, the raising of the dry line high up has solved the problem of touching the ground. However, the clothes gathering at the middle could not be solved by pegging them. We therefore suspected that it is not the matter of how closer the dry line is to the ground or using stronger pegs, but there could be something wrong with the rope they are using. This is because the raising of the dry line high up also creates another problem: it is difficult for people to put things on it with ease. Even raising it still could not eliminate the gathering of the clothes at the middle. What we suggested to be wrong with the rope is that it may have high expansibility which when the load is applied, it expand and therefore sag in closer to ground, letting the clothes to touch the ground. Also when expanded, since the other two ends are tired, it prevents those ends from going down hence having the maximum expansion at the middle which therefore cause the clothes at both edges to all move towards the middle.

We therefore asked ourselves, a material science student, how can we help? Since we knew that the problem arises as a result of the expansion, we therefore decided to look for rope with least expansion when load is applied.

SUGGESTED ROPES FOR DRY LINE

We suggested sisal, and rubber and later added nylon because it is possible that nylon may still be the best as far as the other two is concerned. However, we knew that if any of the two (sisal and rubber) is not better than nylon then the problem will still be the same.

How then do we find out that these three things are different or same in terms of expansibility? Perhaps, nylon could the best among? Our knowledge in material science helped us to determine the strain (change in length over original length) of each one of them. This gives a fair idea of which, among the three have the highest expansibility.

Figure 1. Shows three rope: nylon(green), rubber(orange) and sisal(white).

HISTORICAL BACKGROUND OF THE MATERIAL USED.

Sisal

Sisal is a strong natural fiber obtained from sisal plant called *Agave sisalana*. It offers almost an 80% of its strength due to the high proportion of cellulose. It is durable, inelastic and tough, but has a low maintenance 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 research article published by Gupta et al, the tensile strength of sisal was found to be 132.73MPa.

NYLON

Nylon is a synthetic polymer consisting of Hexamethylenediamine. It was first made in DuPont Chemicals laboratory, USA by passing tit through solutions to obtain its plasticity. Nylon never had a share market until 1940, when it was first introduced in the production of clothing especially stockings for women's wear. Fortunately, the increase in demand for these ropes have led to a keen competition between synthetic products and biodegradable products. Most of the ropes produced are usually nylon, rubber and sisal. According to Laird Plastic, a renowned plastic company recorded 82.7MPa as the tensile strength of nylon. Nylon has a good elasticity, but degrade over time when stayed in the sun and this causes a stretch making it elongated and weak as time goes on. It is also strong and has a good resistance to damage from oil and many chemicals.

RUBBER

Moreover, synthetic rubber is a polymer obtained from petroleum product and has a good elasticity. There is also a natural rubber which is obtained from a thick liquid colloidal suspension called latex obtained from plants. Rubber pre-existed long ago, history has it that ancient inhabitants in Mexico and Central America used rubber to make balls used in a game called Mesoamerican ball game. Later, the Germany made the first synthetic rubber during the War World I to be used for automobile tires. It was then after that the used conducted several researches with the Massachusetts Institute of Technology to find the different properties rubber has hen combined with chemicals. Today the USA is the leading producer of synthetic rubber. Rubber has a very good elasticity, ductile and has a tensile strength of 15-22MPa.

THE DESIGN OF EXPERIMENT

The strand of sisal and rubber were twisted to form a rope in the same way just as how nylon is twisted. This was to make sure that the three ropes are on the same ground as far as the design is concerned. All the three ropes were cut into equal length and their diameters were measured.

COLLECTION OF DATA

With the help of the Pasco machine, force was applied to each of the materials. The force applied and displacement (change in length) were recorded. Knowing the original length of each, the strain was calculated by just dividing the displacement by the original length. The stress was also calculated by dividing the applied force on each rope by its area.

We now have the data, but how do we know whether the three samples are the same or different?

STATISTICAL ANALYSIS

With the bit of knowledge in statistics, we assumed that the mean values of the strain values of each are the same and this was our null hypothesis. We assumed such because it is easy to test whether they are the same than when they are not, hence in case we do test and it is not true then we know they are actually different. We know that when we are able to get our p-value from the data and it is greater than our confident level (confident interval) then our assumption is true otherwise is false.

HOW CONFIDENT ARE WE WITH OUR DATA? (choosing the level of confidence)

Due to the sample size of our data we do not want show too much confidence in our data, nevertheless we will not also undermine it. We are convinced that if the same data is sampled on numerous occasions and interval estimates are made on each occasion, the resulting intervals would tally the true data parameter in approximately 95% of the cases so therefore we chose 95% (0.05) confident interval.

ANALYSING THE DATA

Before we choose any test to perform, we first of all, have to know what type of data we do have. Since our data was measuring length and this can be measured continuously as long as the force is being applied, we were convinced that our data is a continuous data. We also realized that since the three samples are made of different materials as such we could only investigate the difference between them. Having three groups (sisal, nylon and rubber) of data, Anova test is the appropriate. We decided to perform the One way Anova because our samples varied by only one factor, that is, material.

THE ANOVA TEST

The Anova has parametric and nonparametric test. The parametric test is done for data with normal distribution otherwise is nonparametric.

Normality test: Before we decide to choose either of the Anova, we performed the normality test to see whether our data is normal or not. With the help of Graph pad we performed the D'Agostino & Pearson normality test, Shapiro-Wilk normality test and KS normality test.

The table below depicts the results from the normality test.

D'Agostino & 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	0.09931	0.07109
P value	>0.1000	>0.1000
Passed normality test (alpha=0.05)?	Yes	Yes
P value summary	ns	ns

From the table above, it can be seen that the D'Agostino & Pearson normality test gave a p-value (0.0001) , which is less than our CI value (0.05), Shapiro-Wilk normality test also gave a p-value (0.0026) which less than our CI value. Since the p-values are less than our CI value, it implies the data is not normal. Although the KS normality test gave a p-value (0.09931) which is greater than our CI value, the other two test that agreed with one another made us ignore what KS implied.

Performing the One Way Anova (nonparametric);

With the help of the Graph pad, the nonparametric test was performed and the table below depicts the results obtained.

Table Analyzed	One-way ANOVA 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 statistic	115
Data summary	
Number of treatments (columns)	3
Number of values (total)	366

In the table above, it can be seen that the p-value from the Anova test is 0.0001 which way ward smaller than our CI value. Since it is smaller than our CI value it implies the hypothesis which says the mean values of each sample differ from one another. We therefore debunk our assumptions (we reject the null hypothesis). Now we have found out that the three ropes samples are different in terms of expansibility. But we do not know which of these has the greatest expansibility.

POST HOC TEST

Now that we have realized the three samples are different, the only way to find out how different they are from each other, we have to perform the Post Hoc Test. 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 (ANOVA).

The table below shows the results from the Post Hoc Test.

Number of families	1				
Number of comparisons per family	3				
Alpha	0.05				
Dunn's multiple comparisons test	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

From the table above, when the mean value of sisal was compared to that of Nylon, the p-value that was obtained is 0.0001. This value being smaller than our 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

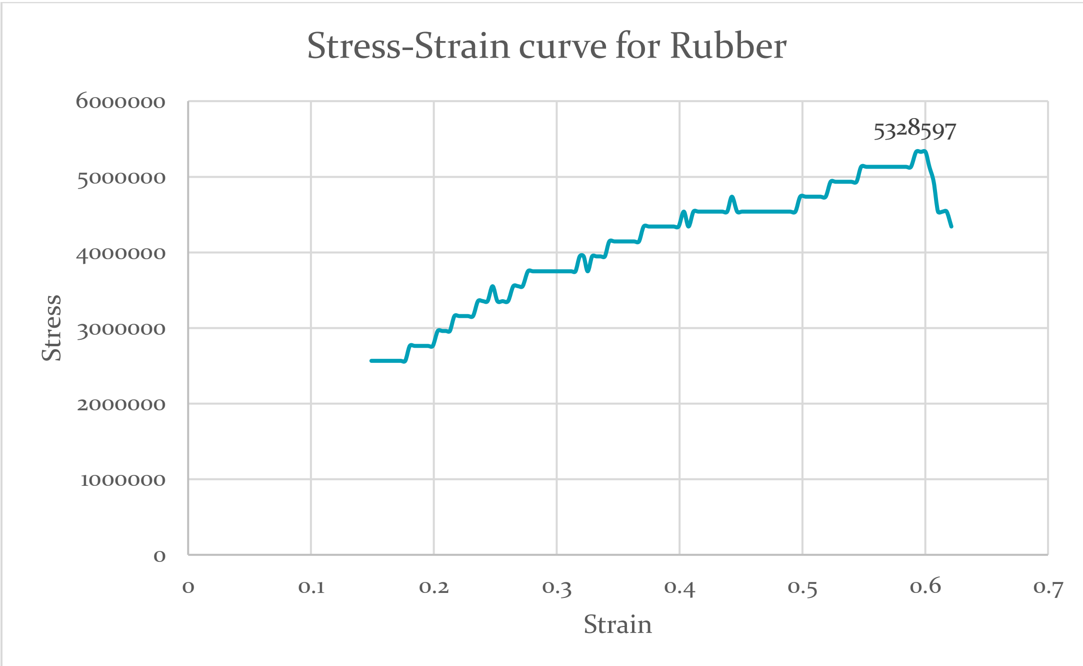
Rubber, the p-value was also 0.0001 which is likewise smaller than the CI value. Therefore, proving the statistical difference between the two. However, when nylon was compared with rubber the p-value was 0.8403 which is greater than our CI value. This implies that there is no statistical difference between the two.

This test shows that statistically, sisal is different from nylon and rubber. However, we do not consider whether sisal has the least expansion or has the most expansion.

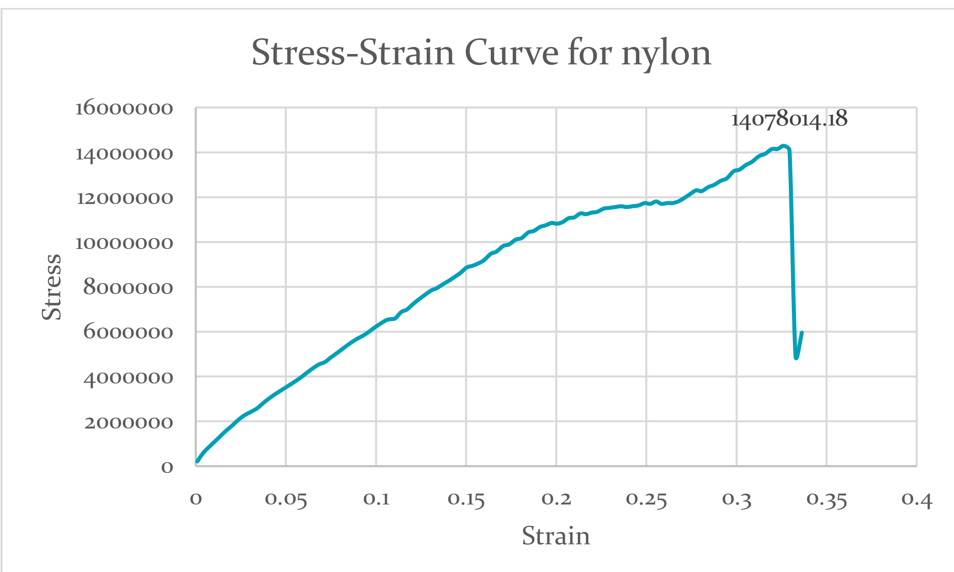
ANALYSIS OF SAMPLES FROM MATERIAL SCIENCE POINT OF VIEW.

Now we have realized that sisal is statistically different from the other, but we could not confirm in what sense it is different from the other two. From our knowledge in material science, we know that when we plot the stress against strain for each of them we can find the Elastic modulus and the ultimate tensile stress. The one with the highest Tensile stress and Elastic modulus has the least expansion.

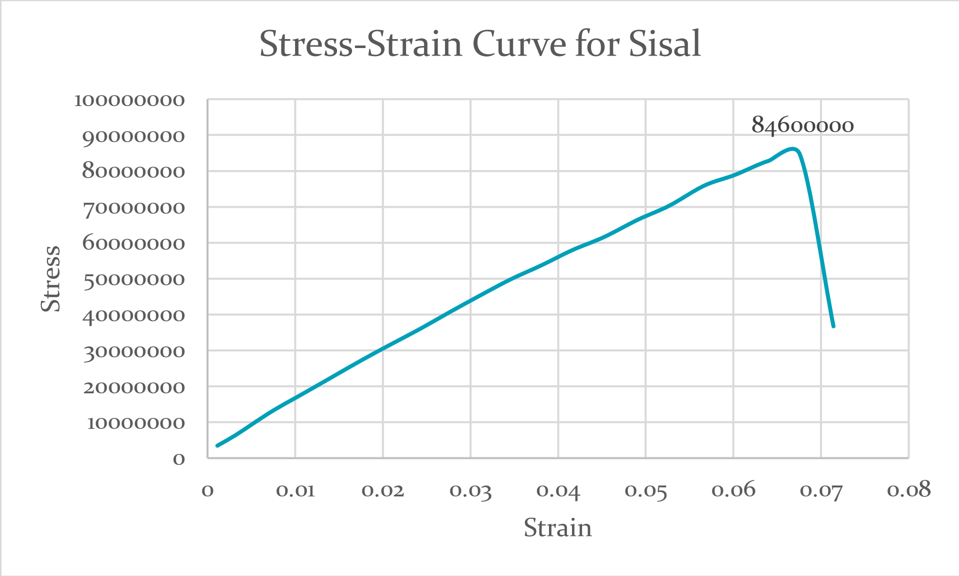
THE GRAPHS OF STRESS VERSUS STRAIN OF THE THREE SAMPLES



Rubber has ultimate tensile stress value of about $5.32 \times 10^{6} Psi$



Nylon has an ultimate tensile stress value of about $1.407 \times 10^{7} Psi$.



Sisal has an ultimate tensile of about $\mathbf{8.46 \times 10^{7}} \boldsymbol{Psi}$.

CALCULATING THE ELASTIC MODULUS FOR EACH SAMPLE

Rope sample	Elastic Modulus	%Elongation at fracture
Sisal	$\frac{3.46 \text{ x } 10^{6} - 0}{1.122\text{x}10^{-3} - 0} = 3084\text{MPa}$	$\frac{6.758312}{12} \text{x } 100\%$ $= 56.3\%$
Nylon	$\frac{13.66\text{x}10^{7} - 12.73 \times 10^{7}}{0.278 - 0.26}$ $= 516\text{MPa}$	$\frac{4.8375}{12} \text{ x } 100\% = 40.3\%$
Rubber	$\frac{2.56 \text{ x } 10^{6} - 0}{0.17675 - 0}$ $=14.5MPa$	$\frac{2.4783}{12} \text{ x } 100\% = 20.6\%$

The 0.02% offset yield of Sisal was 6.5MPa.

Comparing the ultimate tensile strength and elastic modulus of the three samples.

samples	Ultimate Tensile Strength(Psi)	Elastic Modulus (MPa)
Sisal	$\mathbf{8.46 \times 10^7}$	3084
Nylon	$\mathbf{1.407 \times 10^7}$	**516**
Rubber	$\mathbf{5.32 \times 10^6}$	**14.5**

From the above table, Sisal has the highest ultimate which is $8.46 \times 10^7 Psi$ followed by Nylon with an ultimate tensile $1.407 \times 10^7 Psi$. Rubber gave the least ultimate tensile value which is $5.32 \times 10^6 Ps$. The order is still the same in terms of their elastic moduli.

Now, since sisal gave the highest ultimate tensile value, it implies it has the least expansibility. This therefore implies that Sisal is better than Nylon in terms of using as a dry line because it has the least expansibility.

DOES DIFFERENT DESIGN OF SISAL AFFECTS HOW STRONG IT IS?

After we found out that sisal has the least expansion and therefore good for making dry line, we decided to find out how it can be put together to make 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. With the help of the Pasco machine, these two samples were pulled individually and the force applied as well as the displacement (change in length) were recorded. The stress and strain of each was calculated

TEST PERFORMED

We therefore had two groups and hence we performed t-test. Since the data from each sample was independent of each other, we decided to do the unpaired t-test. Because unpaired test is appropriate when data is collected from two different and independent subjects. It was assumed that the mean values of their strain would be same so this was our null hypothesis.

The table below shows the result obtained from the t-test.

Table Analyzed	Unpaired t test data
Column B	twisted
vs.	vs.
Column A	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 column 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

After the t test the p-value obtained was 0.8035 which is greater than our confident level therefore implying that there is no statistical difference between the two design. So either ways of designing a robe for a dry line using a sisal will still have the same strength, statistically.

LIMITATIONS.

Our model failed to predict whether sisal will still hold its “integrity” when subjected to various factors. Our computed values as compared to literature values were way of, which we suspected to be our inability to hold the samples firmly onto the Pasco machine during the experiment.

CONCLUSION AND LESSONS LEARNT.

We therefore come into conclusion that since sisal has the least expansion, it is the best rope for making dry line. However, we run short of materials as such we could not determine the behavior of sisal when it goes through different conditions such as higher temperature and been beaten by rain or when wet. It should therefore be noted that, despite the fact that we have declared it as the best for making dry line, we cannot guarantee how durable it may be when exposed to different conditions. As such, when given the chance next time, we shall therefore consider design our experiment to find out the strength of sisal when subjected to several conditions.

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