SOIL REINFORCEMENT WITH NATURAL FIBERS FOR LOW_INCOME HOUSING FACILITY

Hamid Altaf[1], Tajamul Islam[2], Taib Khan[3], Mohalil Rouf[4], Mansha Tariq[5], Danish Ashraf[6]

[1]B.E Student, Civil Engineering Department, SSM College of Engineering, Kashmir, India
[2]Assistant Professor, Civil Engineering Department, SSM College of Engineering, Kashmir, India
[3]B.E Student, Civil Engineering Department, SSM College of Engineering, Kashmir, India
[4]B.E Student, Civil Engineering Department, SSM College of Engineering, Kashmir, India
[5]B.E Student, Civil Engineering Department, SSM College of Engineering, Kashmir, India
[6]B.E Student, Civil Engineering Department, SSM College of Engineering, Kashmir, India

---***---

Abstract The objective of this study is to Find a natural Fibre to Improve the shear strength and bearing capacity of a cohesive soil. This study includes a proposed protection method to increase the Life of the selected fibre, determination of the optimum reinforcement scheme in terms of Fiber's content and length, and investigation of the reinforced soil through laboratory experiments on footing bearing capacity and slope stability analysis.

Keywords: Shear strength, Bearing Capacity, Cohesive soil, Natural Fibre etc

1. **Introduction** Currently 1.4 billion people live below the international poverty line of $1.25 income per day. Many social problems that currently affect the world are caused by poverty, which causes the deficient access to basic needs for many humans. This is reflected by the frequent occurrence of disasters in low income housing settlements. The most common are: -

- **Fires:** Necessity does not allow most low income housing around the world to follow fire protection precautions.
- **Floods:** Deficient resources do not allow for proper planning, which results in inadequate draining facilities.
- **Earthquakes:** Non-engineered construction does not include a horizontal resistant frame that can withstand seismic forces which results in the collapse of the structures.
- **Landslides:** Low income communities in developing countries tend to build their housing in landslide prone hillsides.

The problems developed by poverty can be summarized into: political and Economic Instability, social and economic dependency and low living standards and access to basic needs.

The disaster that has been minimally addressed for low income settlements is landslides on hillsides. As previously mentioned, the countries with the highest frequency of landslide disasters are the developing nations. These nations have large communities with minimal resources which need to settle on high risk hillsides in order to have access to the cities with the highest employment resources. Additionally, these countries are divided by their high educational disparity, which doesn't allow the least educated groups to understand and evaluate the consequences of unsustainable development practices. Examples of these activities are clearing the vegetative cover in order to grow crops, livestock and developing settlements on hillsides without adequate environmental planning. This inadequate planning does not allow enough water to reach the groundwater table which creates drastic drops in its levels, weakening the soil. Other effects are the erosion of the soil caused by excessive runoff and the addition of significant weight to the running material due to the accumulation of large amounts of water in between houses. These populations not only develop housing settlements in ways that leave the soil completely unprotected but they also build houses right on the slope border

This causes an extreme burden on the shear strength of the soil in the hillside increasing the probability of landslide occurrence.

There are several methods for stabilizing shear strength of slopes, some of the most common ones are:-

- Reinforcing compacted soil layers with steel wire mesh.
- Reinforcing compacted soil layers with geo-synthetics.

- Mixing lime with the soil.
- Randomly mixing Fiber's into the soil.

Most of these methods require a lot of organization, planning, heavy machinery, qualified workers and a high monetary investment; all resources to which these communities do not have access to. We believe future development should be sustainable; therefore need is to help produce a soil stabilization method that has a positive contribution on the environment. Based on this idea and the resources the sample communities have available to them, we determined the reinforcement method that aligns the most with our objectives is the random mix of environmentally friendly Fiber's into the soil. Key concepts within the idea of sustainability for this project are to use materials locally available to these communities and minimally modify the landscape, which would decrease the required work effort.

Increasing the bearing capacity of the soil and the stability of soil in slopes are only two applications of reinforcing the soil with Fiber's. The main effect of this reinforcement is the increase of shear strength of the soil. Previous fibre soil reinforcement studies indicate that the Fiber's significantly increase the shear strength of different types of soils in optimum conditions (Wayne, 1988). According to Terzaghi's and Vesic's soil bearing capacity studies, the bearing capacity of the soil has a direct relationship with the shear strength of the soil. In foundation engineering the bearing capacity of the soil is defined as the maximum homogeneously distributed pressure in direct contact, a soil can withstand before suffering shear failure. Therefore an increase in the bearing capacity of the soil would allow the soil to hold a larger load in the same area, which can prove useful in many aspects of housing development. Some of these aspects are the ability to build larger structures, reduce the size of footings, and easily stabilize soil for roads.

2 CASE STUDY- LOW INCOME COMMUNITIES OF RIO DE JANEIRO, BRAZIL

2.1FIBRE SELECTION:- Fibre selection parameters include:-

- It mustn't be a hazard to its surroundings.
- It must be easily obtainable and inexpensive
- Its preparation method should be simple.
- It must work with the selected soil

Date Fiber's are not easily attainable in other continents (except Asia). Polypropylene Fiber's degrade easily under direct soil exposure and are not easily available in developing countries. Recycled carpet waste is again not easily attainable in developing countries. However, coconut Fiber's (coir) are biodegradable and eco-friendly. Additionally, coconut trees grow widely in tropical areas around the world such as Asia, Central & South America & Africa. Palm trees are grown in abundance in Brazil, the Carribean, Venezuela, Indonesia, Thailand and Kenya among others (Coconut palm tree, 2003).

2.2 COCUNUT FIBRE AS THE REINFORCEMENT MATERIAL FOR THIS STUDY:-

Coconut Fibre is significantly stronger than date palm Fibre, even with a 0.10 mm diameter; far more available than date palm Fibre & cheaper than polypropylene Fibre.

Coir is biodegradable & it takes approximately 20 years to decompose above ground. Few experiments performed by Rao & Balan (2000) suggest that the Fibre will last only 2-3 years in burial conditions. Studies have also shown that coating the Fiber's with a protective layer could increase its durability.

The effectiveness of the Fibre reinforcement depends on Fibre concentration and length. The Fibre lengths range is between 20mm-40mm & Fibre content range expressed in percentage by weight is between 0.00% - 2.50%.

Figure 1: Comparison of Fibre dimensions with a dime

3. TESTING SEQUENCE AND THE STUDIED EFFECTS:

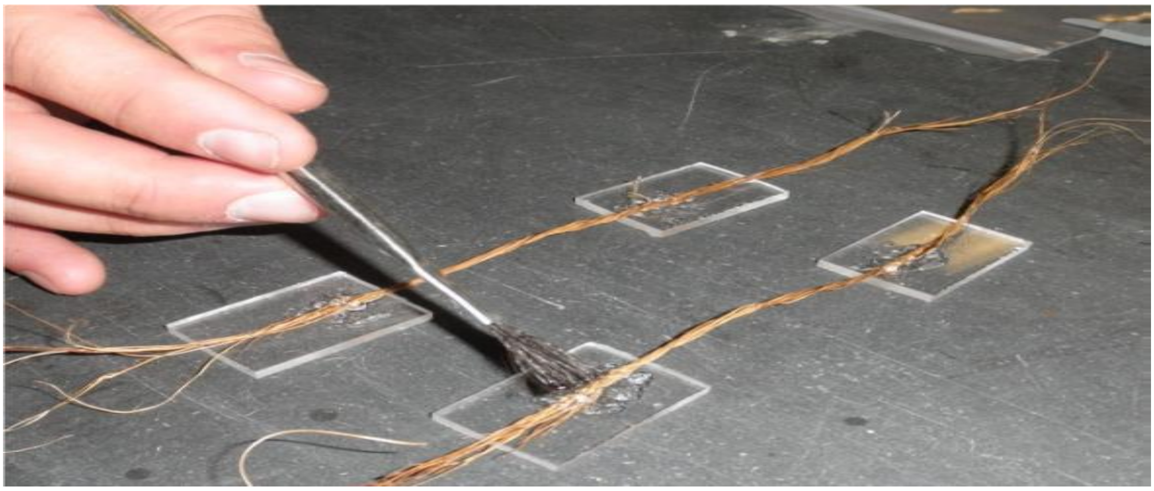
In order to determine the applicability of the coir reinforcement, it is imperative to focus on geotechnical properties- bearing capacity & the slope stability of the soil. The established steps are:-

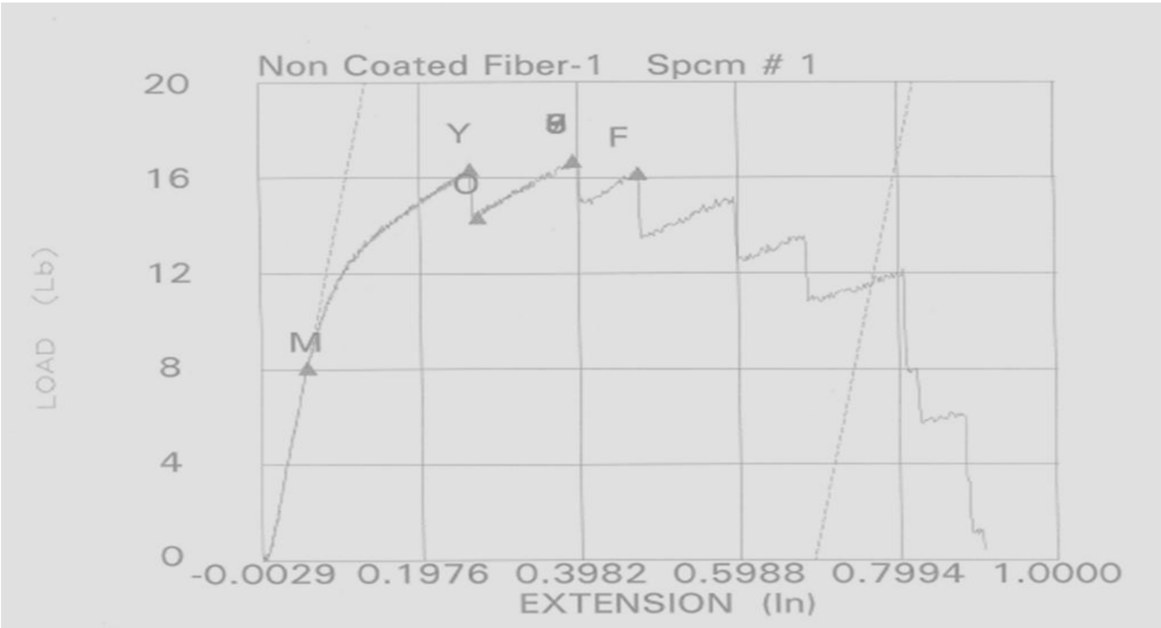
- Evaluation of the effect of Fibre reinforcement on shear strength of soil- this includes the identification of the optimum reinforcement conditions in terms of Fibre length and concentration.
- Testing the impact of an increase in shear strength on the soil bearing capacity.
- Analyzing the benefits of Fibre reinforcement on slope stability- involving the determination of maximum slope angle a hillside can have before failure occurs at normal loading conditions

The testing sequence and the studied effects are summarized in the table below:-

S.NO.	*TEST*	*STUDIED EFFECT*
01.	Ultimate Tensile Strength	Maximum tensile strength of coated & uncoated Fiber's.
02.	Proctor Compaction	OMC of non-reinforced & reinforced soil.
03.	Unconfined Compression (Saturated UCT)	Improvement in shear strength of soil through Fibre reinforcement & improved soil structural integrity.
04.	Indirect Tensile	Change in tensile strength of soil through Fibre reinforcement.
05.	Bearing Capacity	Improvement in bearing capacity of soil through Fibre reinforcement.

3.1 TENSILE STRENGTH TEST OF COCUNUT FIBRE:- Tensile strength of the Fiber's in groups of 10 Fiber's per specimen and 4 specimens for each testing case (group): coated and non-coated Fiber's, were tested. Failure was established as the point where all ten Fiber's in a specimen would break. Figure presents an example graph of the load vs. extension of the specimens generated during the tensile strength test. Every drastic drop in the curve represents the breaking of a Fibre.





10-Fibre Tensile Test Load vs. Extension Graph

Percentage decrease in tensile strength of coated Fiber's with respect to non-coated Fiber's was found to be 11.19%.

3.2 PROCTOR COMPACTION TEST:-

For un-reinforced soil sample, the optimum moist unit weight of 140.44 lbs/ft^3 was attained when moisture content equalled 7.52%. The results of 1.2% reinforced soil sample present an optimum moist unit weight of 138.31 lbs/ft^3 for a moisture content of 7.92%. It can be said that both soil types have optimum moisture content of around 7.72% with standard deviation of +/- 0.28%. Hence, it can be inferred that the Fiber's don't induce any drastic change in the water absorption capacity of the soil.

20% MC Reinforced Soil Sample Preparation

3.3 SHEAR STRENGTH TEST

At Fibre contents above 1.8%, the soil specimen didn't compact well and the layers would easily separate from one another. During the testing, it was observed that the specimens above 1.8% Fibre content never achieved failure since the Fiber's were so close together that they would behave as a mesh that would induce the soil to recompress. In these cases, the maximum loading was achieved. The cylinders without reinforcement compacted much better than those with reinforcement.

For samples with no reinforcement or upto 0.8% reinforcement, cracks would develop only on upper part of the sample at failure. However, the reinforced samples with 1.8% reinforcement or above presented cracks throughout the sample at failure.

During saturated UCT, none of the un-reinforced soil samples endured 72 hours soaking period. The optimal reinforced soil samples had a significantly stronger structural integrity. All 3 samples endured 72 hours soaking period. Average compressive strength was found out to be 238.74 psi. Hence, we conclude that the Fiber's are a great addition for areas with intense rainfall events.

Considering the Fibre lengths of 35mm & 50mm, and their combinations with different percentages of Fibre reinforcement, **the best as per shear strength test was found out to be 2.4% & 35mm sample**.

3.4 INDIRECT TENSILE STRENGTH TEST

The tensile strength of soil increases when the cohesion and friction among its particles increase. It was found out that the tensile strength of the soil decreases with an increase in Fibre percentage. This can be attributed to the fact that the Fiber's don't allow the soil to developing stronger cohesion among particles. Hence, Fiber's reduce the cohesion of the soil by increasing the distance between particles. The increase in friction induced by the Fiber's doesn't compensate this loss. However, the decrease in tensile strength from the un-reinforced sample to the optimum reinforced sample is equal to a 22% which is less than the shear strength increment.

3.5 BEARING CAPACITY TEST:-

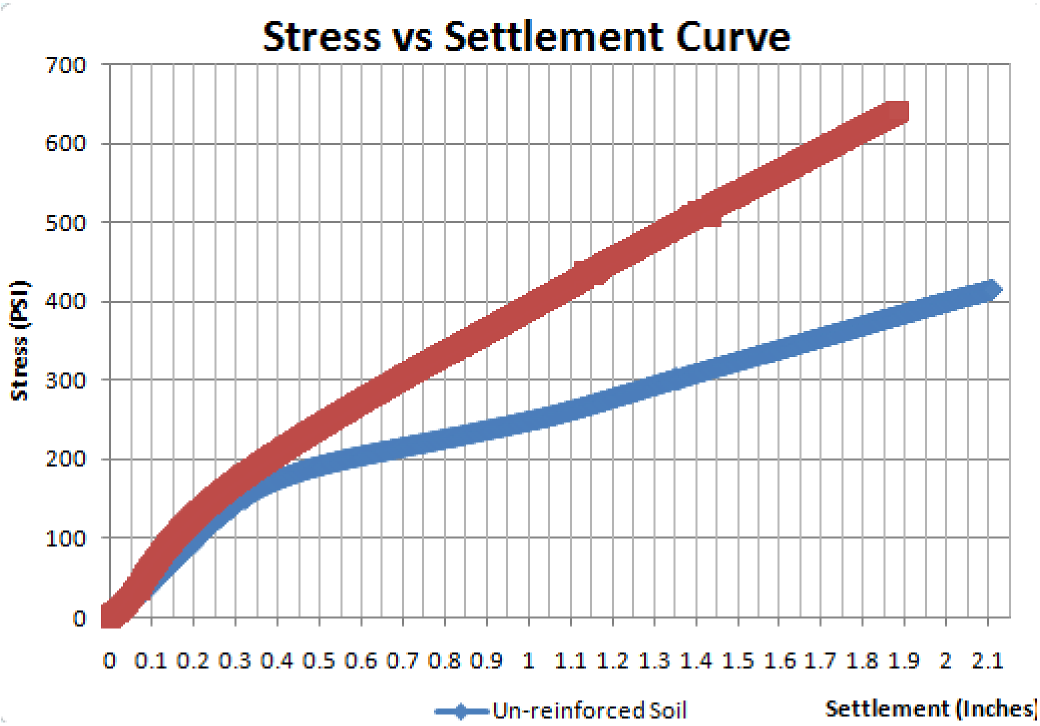
The theoretical values of ultimate bearing capacity for non-reinforced and reinforced soils as per Vesic's bearing capacity equation are tabulated below:-

S.NO.	SOIL	ULTIMATE BEARING CAPACITY
01.	NON-REINFORCED	72.31 Psi
02.	REINFORCED	425.34 Psi

It was decided to use the total allowable settlement for a simple masonry walled structure as the restraining parameter in order to determine the maximum allowable load. According to total allowable settlement table, a simple minimal structure like the low income house, would have a maximum settlement of 1". In the scaled down model (1:7), it would be equivalent to 0.143".

- The BCT for the un-reinforced soil, a maximum stress of 75 Psi was achieved at a settlement of 0.15".
- The BCT for the optimum reinforced soil, a maximum stress of 100 Psi was achieved at a settlement of 0.15".

It can be noticed that the bearing capacity of the un-reinforced soil obtained during the test surpasses the predicted bearing capacity. However, the bearing capacity of the reinforced soil is four times less than the predicted bearing capacity. This difference in the behavior was due to the lack of space for the failure surface to fully develop within the bearing box without being intervened by the box. It is important to notice that, since the failure surface couldn't slide, the failure values for the un-reinforced soil were probably inflated, meanwhile the values for the reinforced soil were under-estimated since the effect of the Fiber's in the restriction of movement couldn't be evaluated.



1:7 Scale Stress-Settlement Curve results of Reinforced and Un-reinforced soils.

4. MODELLING OF SOIL STABILITY WITH SOIL FIBRE REINFORCEMENT:

The following table summarizes the factors of safety obtained for the reinforced and the un-reinforced condition of each slope angle and presents the percentage increment in factor of safety:

S.NO.	*DEGREES*	*SLOPE*	*NON-REINFORCED FOS*	*REINFORCED FOS*	*%AGE INCREMENT*
01.	15	26.79%	1.258	1.791	42.73%
02.	20	36.40%	1.074	1.563	45.53%
03.	25	46.63%	0.949	1.369	44.26%
04.	30	57.74%	0.957	1.344	40.44%
05.	35	70,02%	0.908	1.309	44.16%
06.	40	83.91%	0.879	1.112	26.51%
07.	45	100%	0.845	1.093	29.35%

As it can be noticed, there is not a clear pattern in the relationship, but a trend line can be established which illustrates the effect slightly decreases with an increment in slope. As most of the slopes in Rio de Janerio, Brazil vary between 20° to 29°, therefore the modeling permits to imply that adding the reinforcement on the top 3 ft of soil will improve the slope stability by at least 40%.

5. CONCLUSIONS

The following conclusions are obtained from the experimental study as well as case study:-

- Fiber's don't induce any drastic change in the water absorption capacity of the soil.
- The decrease in the tensile strength from the un-reinforced sample to the optimum reinforced sample is less than the shear strength increment.
- The insertion of date palm Fibre into the soil can increase the non-reinforced soil bearing capacity upto 26 times (Marandi, 2008).
- The maximum increase of strength due to coconut Fibre is 3.5 times that of the non-reinforced soil (Babu & Vasudevan, 2008).
- The length of the Fiber's should be less than 50mm to increase the consistency of the soil behavior.
- The reinforcement significantly improves the structural integrity of the soil.
- A preservation process for the Fiber's should be such that it doesn't significantly decrease the strength of the Fiber's. It should neither have any detrimental impacts on environment nor be a health hazard.
- The soil optimum moisture content should be reached before adding the Fiber's and then the Fiber's should be added slowly. This prevents clumping together of Fiber's above the soil particles.
- Initial moisture content of the Fiber's should be tested in order to increase the precision in measurement of the moisture content of the reinforced soil. It would also be beneficial to observe the absorption capacity of the Fiber and test any change in strength & stiffness.
- The implementation of the optimum Fiber reinforcement on the upper three feet of a slope significantly increases the soil bearing capacity and therefore its stability.
- Implementation of reinforcement increases the factor of safety by an average of 39%.
- A 25˚ to 30˚ slope can be fully developed for low income housing in an inexpensive and safe manner by cutting terraces and reconfiguring the slope to a 20˚ angle.
- A 30˚ to 45˚ slope can be reinforced to ensure safe development; the method of terracing would require extensive earthwork.

6. BIBLIOGRAPHY:

[1] Alexander, David. "On the Causes of Landslides: Human Activities, Perception, and Natural Processes." Environmental Geology Volume 20.Number 3 (November 1992): 165 to 179. Springer Link

- http://www.springerlink.com/content/x144p415334p6367/

[2] . Babu, Sivkumar G. L., and A. K. Vasudevan. " Strength and Stiffness Response of Coir Fibre-Reinforced Tropical Soil." 20.9 (2008): 571-577-577.

[3] Coduto, Donald P. (1998). Geotechnical Engineering: Principles and Practices. Prentice-Hall

[4] Day, Robert. Geotechnical and Foundation Engineering: Design and Construction. Illustrated ed. McGraw-Hill Professional, 1999.

[5] Fred, Wayne W. "Fibre Reinforced Soil and Method." 1988. <http://www.freepatentsonline.com/4790691.html>.

[6] Ginzburg, L. K., E. L. Korchagina, and V. B. Shvets. "Reinforcement of Foundations in Weak Saturated Silty-Clayey Soils." Soil Mechanics and Foundation Engineering 32.6 (1995): 207, Springerlink: <http://www.springerlink.com/content/bkv86442826t0270/>.

[7] Sassa, Kyoji, and Paolo Canuti, "Landslides - Disaster Risk Reduction" Ed. Kyoji Sassa and Paolo Canuti. Illustrated ed.Springer, 2008. 50 - 62.

[8] Shah, Anup. "Poverty Around The World." 2009. <http://www.globalissues.org/article/4/poverty-around-the-world.

7. BIOGRAPHIES:

Hamid Altaf, Student of B.E civil Engineering Sem 8th, SSM College of Engineering. He Has 5 Research Papers in National and International journals.

Er Tajamul Islam, Assistant Professor at Civil Department SSM College of Engineering. He Graduated In B.E from S.S.M college Of engineering & M.tech (Transportation Engineering) From Kurukshetra University Haryana. He has 13 paper publications to his name in various national and international Journals

Taib Khan, Student of B.E civil Engineering Sem 8th, SSM College of Engineering.

Danish Ashraf, Student of Civil Engineering Sem 6th, S.S.M college of Engineering

Mohalil Rouf, Student of Civil Engineering Sem 6th, S.S.M college of Engineering

Mansha Tariq, Student of Civil Engineering Sem 6th, S.S.M college Of Engineering