

# Investigation of Mechanical Properties of Mud Concrete with Coconut Fiber Reinforcement

Harsha Galabada  
 Department of Civil Engineering  
 University of Moratuwa  
 Moratuwa, Sri Lanka  
 hyasasiri@yahoo.com

P. Dhammika Dharmaratne  
 Department of Civil Engineering  
 University of Moratuwa  
 Moratuwa, Sri Lanka  
 makway.cons@gmail.com

Himahansi Galkanda  
 Department of Civil Engineering  
 University of Moratuwa  
 Moratuwa, Sri Lanka  
 himahansi.galkanda@gmail.com

Rangika Umesh Halwatura  
 Department of Civil Engineering  
 University of Moratuwa  
 Moratuwa, Sri Lanka  
 rangikauh@gmail.com

**Abstract**—Mud concrete was a sustainable innovation, invented to replace existing conventional construction materials with sustainable material. Mud concrete consists of soil and cement along with water. In terms of sustainable construction, cement which act as the stabilizer in mud concrete should be kept lesser as much as possible, according to its potential environmental issues. Therefore, evaluation of ability to enhance the mud concrete properties by adding some admixtures is essential. There are no of admixtures used in the construction industry with many forms, such as liquid, solid, semisolid or fiber. In most of the studies fiber was used as an admixture to improve the strength performance of construction materials. Hence, evaluate the strength performance of mud concrete with fiber is important to reduce cement in sustainability contest. Therefore, this study was investigated the effect of natural fiber length on compressive strength and strength variation with water content of mud concrete with fiber. According to the results, the highest strength was recorded with the fiber length of 60 mm and the compressive strength was decreasing with the increasing water content. The study concluded that the optimum fiber length is 60 mm and there is a negative correlation between compressive strength and water content.

**Keywords**— *coconut fiber reinforcement, compressive strength, mud concrete, natural fiber*

## I. INTRODUCTION

Use of locally available materials and technology without sacrificing the strength and life of the structure is important with respect to sustainable construction thus sustainable construction materials. As a result, this century has witnessed several remarkable achievements in sustainable construction through the development of construction materials that have less harmful effects to the environment, less demand for non-renewable resources, etc.

The natural material, ‘soil/mud’, has been used in construction industry for thousands of years back. However, there are numerous researches being carried out by many researchers worldwide as well in Sri Lanka, interrelated to soil as a construction material [1][2][3][4]. Though, soil has low tensile and shear strength which are strongly dependent on the environmental conditions, according to literature, soil can

be strengthened by adding suitable stabilizer(s) to achieve the mmechanical properties required of a proper construction material[5]. Currently, there are many essential novelty performances using soil as more sustainable construction material. Improve the properties of soil using cement as a stabilizer and innovation of mud concrete is a successful innovation of resent literature having may extra ordinary characteristics and currently using many charity projects [6][7][8] [9].

The coconut fiber is a natural fiber which obtained from the husk of the fruit of the coconut palm tree (*Cocos nucifera*), which grows extensively in tropical countries. Although coconut palms grow throughout the world’s tropical regions, the vast majority of the commercially produced coconut fibers come from Indonesia, Philippines, India, Brazil, Sri Lanka, Thailand, Vietnam, and Malaysia[10]. The diameter of coconut fibers in different researches is approximately equal and value may be within 0.1-0.5 mm. The tensile strength of the coconut fibers is somewhat different. However, it may be within the 100 - 200 N/mm<sup>2</sup> based on the literature. The density of coconut fiber may be within 0.67 – 1.00 g/cm<sup>3</sup>[11]. Chemical composition and microfibrillar angle of the coconut fibers is shown in Table I.

TABLE I. CHEMICAL COMPOSITION AND MICROFIBRILLAR ANGLE OF THE COCONUT FIBERS [12]

Chemical Composition and Microfibrillar Angle	Unit (weight%)
Lignin	40-45
Cellulose	32-43
Hemicellulose	0.15-0.25
Pectin	3-4
Water soluble	5
Ash	2
Microfibrillar angle (degree)	30-49

Mud concrete is produced using soil as aggregate, cement as a stabilizer with water to form a concrete. The concept of this innovation is to introduce a sustainable construction material without sacrificing strength and durability characteristics. In terms of sustainable construction material, cement which acts as the stabilizer in mud concrete should be kept lesser as much as possible. Therefore, evaluation of ability to enhance the mechanical properties of mud concrete by adding some admixtures is essential in time being. Therefore, this experiment was designed to evaluate the behavior of mud concrete with natural fiber as an admixture.

II. EXPERIMENTAL PROGRAM

This experiment was designed to study the variation of mechanical properties of mud concrete when composite with coconut fiber as a fibrous admixture. The experiment was carried out in two stages.

Stage 1- Variation of compressive strength with varying amount of water on fiber reinforced mud concrete.

Stage 2 - study the effect of fiber length to the compressive strength. All experiments were carried out in the material laboratories of university of Moratuwa, Sri Lanka.

A. Materials

Materials used were soil as main matrix, cement as stabilizer, coconut fiber fiber as fibrous material and water as binder (Fig. 1).

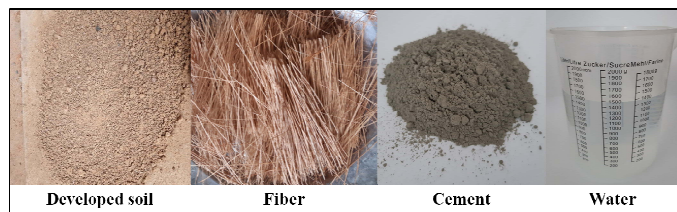


Fig. 1. Materials used in the experiment

Soil (Main matrix):

Required amount of soil was extracted from the premises of University of Moratuwa and randomly selected three samples were subjected to sieve analysis to identify the particle size distribution of the extracted soil. According to the average test results received in sieve analysis, the extracted soil contains 7% fine particles (sieve size 0.425mm>), 63% sand (sieve size 0.425mm<sand<4.75 mm) particle and gravel (sieve size 4.75mm<gravel<20 mm) 30%. For the mud concrete blocks, the best fine particle content is < 10%, Sand content 55-60% , Gravel content 30-35% and maximum gravel size is 20 mm[8] . Further Udawatta et.al 2017 mentioned in their scholar that for mud concrete paving blocks, the best fine particle content is 5% , Sand content is 60% and Gravel content is 35% [6]. Therefore, the laboratory experiments were initiated with developing soil to have the compositions of fine particle content 5%, sand content 60% and gravel content 35% (Fig. 2). To develop the soil in this required level of particles gravel and sand particles were added in calculated quantity. Sieve analysis was carried out to confirm the particle

size distribution. Once the soil became its correct compositions, this soil was used as main matrix to produce the reinforced mud concrete.



Fig. 2. Existing soil preparation to required composition

Cement:

The cement used in this research was Ordinary Portland cement and 15% cement; from developed dry soil weight, was added as a stabilizer.

Water:

Pure drinkable water was used. In first case, amount of water added was changed to start from 3,750 ml which is the minimum water requirement to produced self-compacting mud concrete and increase by 250 ml up to 4,750 ml which is the maximum water quantity that can be used to prepare mud concrete without segregation [6] . In the second stage water quantity was maintained as a constant during the experiment.

Fiber:

Mainly there are different types of fibers such as naturally occurring fibers and synthetically developed fibers. The several research data can be found through the literature evident that the fiber use to enhance properties of construction materials[13] [14] [11][15]. Abundantly available natural fiber named as coconut fiber fiber was selected in this studies. The coconut fiber is available in two types as brown fiber and white fiber. Brown coconut fiber fiber was selected for this experiment. Coconut fiber fiber extracted from the outer shell of coconut was clean to remove coconut fiber fiber dust and make as small buddle. Then the coconut fiber fiber was cut in to several lengths as required using manually operated machine.

Fig. 3 shows the preparation of coconut fiber in required lengths. Fiber amount was calculated as a percentage from developed dry soil weight.

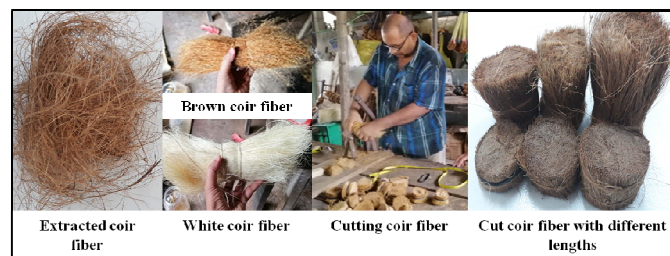


Fig. 3. Preparation of coconut fiber fiber in required lengths

**B. Preparation of Reinforced Mud Concrete**

The extracted soil samples were developed by adding gravel and sand to make soil to be gravel (sieve size  $4.75\text{mm} < \text{gravel} < 20\text{ mm}$ ) 35%, sand (sieve size  $0.425\text{mm} < \text{sand} < 4.75\text{ mm}$ ) 60% and fine particle (sieve size  $0.425\text{mm} <$ ) 5%. Cement % and fiber % were calculated from total dry soil weight. First the prepared soil was thoroughly mixed with 15% cement in dry condition. Then the fiber was added and all the ingredients were thoroughly mixed again in dry condition prior to adding water. Then measured amount of water was added bit by bit and mixed well. Fig. 3 shows the materials which are used to prepare the reinforced mud concrete. The fiber reinforced mud concrete in green stage mix was poured in to the cubes in three layers by compacting them manually. In the first stage fiber length 60 mm kept as constant and the second stage was preceded by maintaining the constant water amount as 4000 ml. The mix proportions were as given in Table II and Fig. 4 shows graphical representation of the specimen preparation plan.

TABLE II. REINFORCED MUD CONCRETE MIX PROPORTIONS

Mix designation (F; i=1 to 12)	Components						
	Gravel (G) %	Sand (S) %	Fine (Clay+Silt) partials (CS) %	Cement (Ce) %	Fiber length (FL)(mm)	Fiber (FP) %	Water (W) (ml)
Stage -1							
F1	35	60	5	18	60	0.4	3750
F2	35	60	5	18	60	0.4	4000
F4	35	60	5	18	60	0.4	4250
F5	35	60	5	18	60	0.4	4500
F6	35	60	5	18	60	0.4	4750
Stage -2							
F7	35	60	5	18	20	0.4	4000
F8	35	60	5	18	40	0.4	4000
F9	35	60	5	18	60	0.4	4000
F10	35	60	5	18	80	0.4	4000
F11	35	60	5	18	100	0.4	4000
F12	35	60	5	18	120	0.4	4000

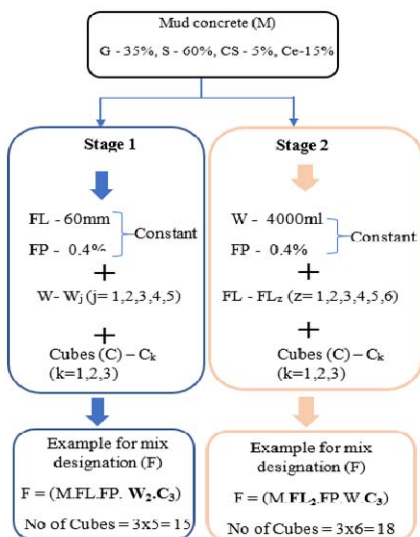


Fig. 4. Graphical representation of specimen preparation plan for experiment

Standard size (150mmx150mmx150mm) cubes were prepared. For stage 1, 15 numbers of samples were cast. Thereafter, 18 numbers of samples were prepared for the second stage. Three cubes were cast to take the average strength values for each and every mix designs. In addition, three samples from each mixed were kept in oven under the 105°C for 24hr to measure the moisture content. Fig. 5 shows the mixing and preparation of sample cubes.



Fig. 5. Cube sample preparation

**C. Compressive Strength Test**

The compressive strength test was carried out after 28days. The compressive load was applied using a universal compressive strength testing machine with a capacity of 2000kN under a constant rate of 6.8 kN/s until failure the specimen. The tests were performed in accordance with the BSEN 12390-3:2009 [16]. Fig. 6 shows few steps of specimen's testing.

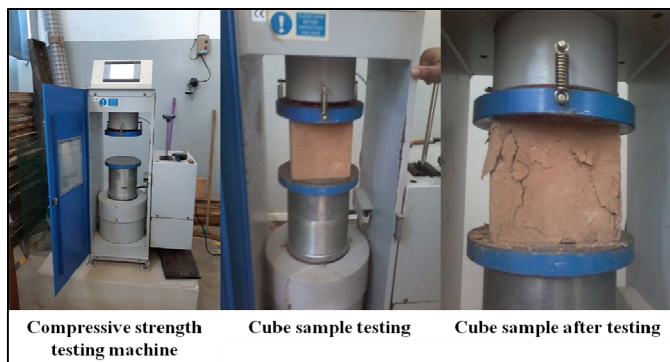


Fig. 6. Compressive strength testing of sample cubes

### III. RESULTS AND DISCUSSION

The compressive strength results taken were analyzed. Fig. 7 shows the failure pattern for fiber reinforced mud concrete. The variation of compressive strength with moisture content is shown in Fig. 8. According to the results obtained, compressive strength shows the linear variation with water content having -0.5 gradient. However, according to the previous experiment results the variation of compressive strength of mud concrete without fiber shows the linear variation with different gradient [17].



Fig. 7. Failure pattern of fiber reinforced mud concrete

Though maintaining the constant water contents, moisture content of oven dried samples observed some variations. Since, the moisture content drastically influenced for the properties of the mud concrete the observed compressive strength results was brought to compressive strength for same moisture content value using stage 1 results. Variation of compressive strength with fiber length was shown in Fig. 9. Addition of fiber initially shows the increment in compressive strength and further increase in fiber length cause to decrease the strength. The optimum compressive strength displays, when the coconut fiber length is 60 mm.

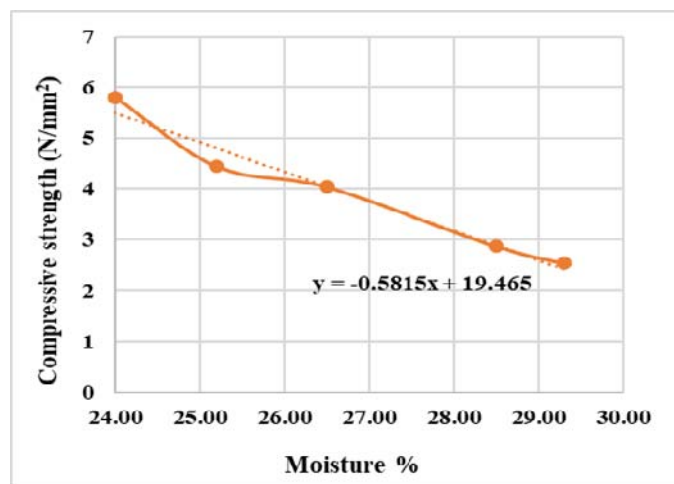


Fig. 8. Variation of compressive strength with water content

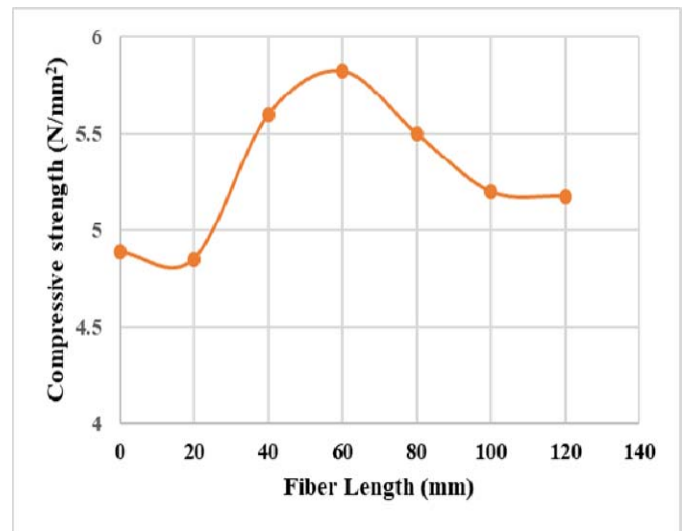


Fig. 9. Variation of compressive strength with fiber length

The compressive load tolerates by combination of the three types of bond in the mud concrete as stabilized soil-soil bond, soil-fiber bond and fiber-fiber bond. The compressive strength shows slight increment of adding fiber. This slight increment says that the large percentage from applied load was tolerated by the soil-soil bond and with the support from the other two. Further, the increase is only for fiber length up to 60mm and further increasing fiber length it is cause to decrease of compressive strength. This is because, when the fiber length increases when the mixing of soil with fiber, individual fibers are overlapped and twisted around each other forming soil-fiber bond. Hence, amount of soil-fiber bond increase decreasing amount of soil-soil bond which is the main type of bond effect to compressive strength.

### IV. CONCLUSIONS

This study presents the behavior of mud concrete with coconut fiber. Based on the results, it can be concluded that the addition of coconut fiber, increases the compressive strength of mud concrete. However the length of fiber is affected for the compressive strength and observed optimum length is 60mm. Enhancing the interfacial bond properties of coconut fiber by adopting suitable treatment might be further enhanced compressive strength. It causes to reduce the amount of cement content used for mud concrete. The compressive strength of fiber reinforced concrete decreases with increment of water.

### V. FURTHER STUDIES

Further studies are required to find out the effect of fiber percentage to properties of mud concrete. The method to enhance the fiber-soil bond, hence further increase properties of fiber reinforced concrete to reduce cement which is still unsustainable ingredient used for production of mud concrete need to study. The ability to use of different types of fiber also required to study.

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