© November 2022 | IJIRT | Volume 9 Issue 6 | ISSN: 2349-6002

Enhanced Performance of Earthen Blocks, Modified by Geo-net and Coir Fibers

Abhijit Das[1], Jhuma Mitra[2], Bharat Sarkar[3], Prasenjit Das[4], Debraj Das[5]
[1]*M Tech Student, National Institute of Technology Agartala, India*
[2,3,5]*Assistant Professor, Tripura Institute of Technology, India*
[4]*Research Scholar, National Institute of Technology Silchar, India*

Abstract— **Earthen structures are known to be cost-effective and relatively simple to construct, making them ideal for remote areas and low-income groups. These structures can be built with locally available eco-friendly materials. Such designs are typically made of soil blocks. However, such blocks are weak in compressive and shearing strength. The main objective of this work is to compare earthen blocks modified by geonet and coir fibers with rammed earthen blocks of the same soil. In terms of compressive and shear strength, to verify this method of soil modification. The modification is accomplished by combining coir fibers with soil and laying out the geo-net horizontally with uniform vertical spacing. The block is made up of well-graded soil, coir fibers (at a rate of 1% of the soil's weight), and geo-net (placed horizontally with uniform spacing) and measures 7 x 7 x 7 cm. 6 days in the open air and one day in the oven at 100 C. There were three types of blocks made: I standard rammed earth blocks, (ii) blocks modified with coir fibers, and (iii) blocks modified with both coir fibers and geo-net. Three blocks from each type were tested and compared in terms of compressive and shear strength. The results show that the blocks modified with geonet and coir fibers have significantly increased compressive and shear strength.**

Index Terms**—Soils, geo-net, coir fiber, rammed earthen blocks, modified earthen blocks, shear strength, compressive strength.**

I. INTRODUCTION

Since ancient times, raw earth has been used as a building material. However, it has been ignored since the invention of burnt bricks and cement/lime binding materials. Such earthen structures are now only found in Africa, parts of India, and China. However, the production of burnt bricks and cement significantly negatively impacts the environment. Eco-friendly structures are currently being researched. Earthen blocks that have been modified are in high demand. These blocks are ideal for rural areas where bricks cannot be made, as well as for lower-income groups. These blocks are also suitable for road shouldering, themed earthen buildings in parks, and other tourist attractions. However, these blocks lack shear and compressive strength. As a result, these blocks are modified in various ways, each of which has some drawbacks—explicitly designed for strength and durability. Blocks can be modified by using either binding materials or reinforcement forms. Previous research indicates they fail primarily due to a loss of bonding among soil particles, a heterogeneous distribution of stresses, and service loads. Reinforcement and modification are used in this method to increase the load-bearing capacity of the blocks through homogeneous stress distribution. These blocks are made of well-graded soil, coir fibers (at a rate of 1% of the soil's weight), and geo-net (7 x 7 x 7) cm in size. Six days in the open air and dried in the oven for one day at 100°C.

Three types of blocks were manufactured, they are as follows:
a) Ordinary rammed earth block. b) Block modified with coir fibers. c) Blocks modified with both coir fibers and geo-net.

The objectives of the present study are as follows:

a. Justify that modification by coir fiber and geo-net has a significant effect on shear and compressive strength.
b. To study the degree of improvement of different modifications, related to this study.
c. To study the properties of the sample soil.
d. To study the suitability of blocks, made by the modified soil.
e. To study the behavior of the blocks under compressive load.

II. LITERATURE REVIEWS

Previous researches have studied that the relation between physical properties of soil blocks and different method of modifications. These are discussed as follows:

Abdellah Mellaikhafi (2021) : According to his research this study deals on the one hand, with experimental characterization of the thermophysical properties of adobes made from raw earth reinforce with five different plant waste fiber from palm trees in the Draa-Tafilalet region in South-eastern Morocoo (pinnate leaves, palm fiber mesh, palm trunk, petiole and palm cluster) and on the other hand, with numerical simulation based on the one dimensional numerical model to evaluate the effect of the wall constructed in studied adobe on the heat flux and the thermal comfort of the building. The results of the experimental study show that the thermal properties of the samples improve and are different depending on the types of fiber incorporated. Indeed, the insulation property improves at least by about 30% for a mass fraction of 6% of the petiole and palm fiber mesh and at most 48% for 6% of pinnate leaf fiber.

1. Francisco R. A. Ziegler-Rivera etal. (2021): Acid copper sulfate solution (ACSS) like mine spills are mainly responsible for the effects in soils and sediment due to which we investigate the ACSS. By applying the method of X-ray tomography computed series of soil porosity images before and after each irrigation with ACSS through microscope analysis to the modification of original porosity with the interaction of soil particals into the following way:

i)Decrease in the number ans size of pores in the soil particals.

ii) Increase in the number and size of pores in the sediment to passed the solution into the soil. In this way we can protect site and free from this effect.

HanifiBinici et al. (2008): The materials that we used in building construction should have the sound insulation property. The material used in the fiber reinforced mud brick as a sound insulating material is basaltic pumice found from southern Turkey. The pumice consists of 85% volcanic glass and 15% phenocrystic feldspars along with hematite minerals. The results show that the basaltic pumice improve the sound insulation performance of fiber reinforced mud bricks.Hakan A. Nefeslioglu et al. (2013): On the geo-mechanical properties of clay stones and mudstone collected from Firuzkoy area of Turkey. The term mudstone includes both rock types of siltstone and clay stones together. Mudstone consist of more than 50% of sedimentary rocks.Ime Akanyeti (2020): The contribution of ordinary Portland cement production to global greenhouse gas emission is estimated about 5-7%. For environmental protection and sustainable development, a large number of studies have been conducted on production of bricks from waste materials. In order to produce such brick,coal ash, treated and untreated ciggarate butts(CB) has been used for study. The produced light-weight bricks with CBs can be used as a material for interior structures. The water absorption values of the bricks with untreated CBs are considerably higher. Hence, the chemical treatment of the CBs improves the density of the bricks. M. S. Moka et al. (2010): We have studied, they used Geotextile and Geomembranes to improve the drainage facility, life span and strength characters of soil by providing reinforced like structure. They found that Tri-planar geonet has more effective resistance to the long-term thickness reduction behavior as compare to bi-planar geonet. The Tri-planar geonet with unit weight 1700g/sq.m has higher designing normal pressure from bi-planar geonet with unit weight of 920g/sq.m.

Meriem Saidi et al. (2018): The reliability of earthen building mainly depends on the thermal and hygric properties of the material. To increase such properties the soil used in these are stabilized by different materials, in this case they are stabilized by cement or lime contents of 5%, 8%, 10%, 12%. The results show that the thermal conductivity is increased due to it. Mahgoub M. Salih et al. (2019):In this paper we have used two types of fibres which is chicken feather fibres(CFF) & sugarcane bagasse fibres(SBF)to investigated the effect of CFF & SBF on soil bricks with adopted fibre length of 15 mm & thoroughly mixed with the soil by weight using an amount of 7%CFF & 5%SBF.After then find out the bulk density ,water absorption, durability, compressive & tensile strength of soil bricks. The results of samples were found to be 98.8% & 78.8% stronger respectively in compression compare to control mix.

2. N. Lingeshwaran et al. (2020): Brick work structures experiences a lot of harm during seismic tremors, resulting in huge loss of lives. The main objective of the paper was to obtain and compare the

seismic vulnerability of un-reinforced masonry walls against a reinforced one using linear static analysis using stadd pro. The final outcome of this performance analysis declared the efficiency of Reinforced masonry walls to be higher than the masonry walls without reinforcement under both axial and seismic loads.

III. METHODOLOGY

A soil sample was taken from the Jirania brick manufacturing factory. Soil samples were collected 50 cm below the ground surface. Tools such as a trowel, spade, and augur were used for sample collection. The samples were labeled, sealed, and transported to the laboratory for analysis in thick polythene bags.

The geotechnical properties of soils were determined at the Tripura Institute of Technology's Civil Engineering Department's Geotechnical Laboratory in Narsingarh, Agartala. The following methods were used to test various parameters:

a) Specific gavity:

It is the ratio of the weight in air of a given volume of dry soil solids to the weight of equal volume of distilled water at 4°C . Particles passed through 4.75 mm IS sieve were used for determining specific gravity with the help of density bottle. It is also defined as the ratio of density of solid to the density of water.

b) Water content

Water content is the ratio of the weight of water to the weight of dry materials. It is expressed in percentage, but used as a decimal in computation and denoted by. The water content of the fine-grained soils, such as silts and clay, is generally more than that of the coarse-grained soils, such as gravels and sands. The water content of some of the fine-grained soils may be even more than 100%, which indicates that more than 50% of the total mass is that of water. Water content was determined by oven drying method (IS:2720-Part II, 1973) in laboratory. The natural moisture content gives an idea about the state of soil in the field.

c) Grain size analysis

The field soil first dried in oven and all lumps are broken into pieces. For grain size analysis, soil sample of 500 gm was sieved through a set of sieves ranged from 4.75 mm to 75 µm. The entire set of sieves was kept on electric sieve shaker machine and operated for 10 minutes. Percent finer for different sizes of the particles retained on different sieves were calculated.

d) Atterberg Limits

The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit and liquid limit. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state, the consistency and behavior of a soil is different and consequently so are its engineering properties. Thus, the boundary between each state can be defined based on a change in the soil's behaviour.

e) Standard Proctor test

Soil compaction is the optimum moisture content at which a given soil type becomes the densest and achieves its maximum dry density by removing air voids. To understand the compaction characteristics of different soils with changes in moisture content, soil compaction tests are performed using Proctor's test. Finally, this test demonstrated a relationship between water content and dry density. The water content at which the maximum dry density was obtained was calculated using the test's connection.

f) Compressive Strength Test

A compression test is a mechanical test in which a material or product responds to forces that push, compress, squash, crush and flatten the test specimen. Compression testing is a fundamental mechanical test, similar in nature to tensile and bend tests.

Compression tests characterize material and product strength and stiffness under applied crushing loads. These tests are typically conducted by applying compressive pressure to a test specimen using platens or specialized fixtures with a testing machine that produces compressive loads.

g) Direct Shear Test

The test is earned out on a soil sample confined in a metal box of square cross-section which is split horizontally at mid-height. A small clearance is maintained between the two halves of the box. The soil is sheared along a predetermined plane by moving the top half of the box relative to the bottom half. The box is usually square in plan of size 60 mm * 60 mm.

IV. RESULTS AND DISCUSSIONS

a) Characterization of sample soil

Grain size analysis and specific gravity test are carried out on the soil sample. The results obtained are displayed in tabulated form. As per grain analysis, it is found that the sample soil is of Clayey sand and is well graded in composition.

Table 4.1 Sieve Analysis of sample soil

Sieve size in mm	Weight of sieve in gm	Weight of sieve + soil in gm	Weight of soil retained in gm	Percent retained	Cumulative percent retained	Percent finer [100-(6)]
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
4.75	400	400	0	0	0	100
2.00	375	395	20	9.76	9.76	90.24
1.18	365	405	40	19.512	29.272	70.728
0.425	380	415	35	17.07	46.342	53.658
0.300	380	390	10	4.878	51.22	48.78
0.150	320	365	45	21.95	73.17	26.83
0.075	300	345	45	21.95	95.12	4.88
Pan	425	435	10	4.878	99.99	0

From the above curve we can see that D10, D30 and D60 sizes for this sample are 0.09, 0.17, 0.70 mm respectively. These sizes are used to calculate co-efficient of curvature (Cc) and co-efficient of uniformity (Cu). It is found that Cu is 7.67 and Cc is 1.45. As Cu is greater than 6 end Cc falls between 1 and 3 , hence we can say the soil is well graded.

The results obtained in Specific Gravity test is given in tabulated form, as shown below:

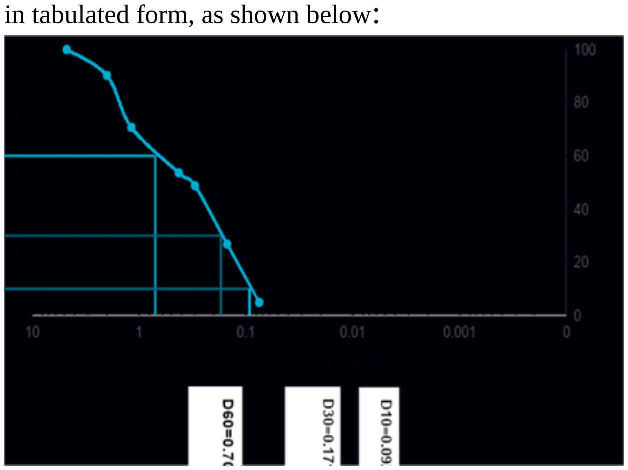

Fig: 4.1 Grain Size Distribution of Sample Soil

Table 4.2 Specific gravity of sample

SL. No.	Observations	1	2	3	4	5
1	Weight of density bottle (W_1 gram)	20.07	20.07	20.07	20.07	20.07
2	Weight of density bottle with dry soil (W_2 gram)	35.07	35.07	35.07	35.07	35.07
3	Weight of density bottle with dry soil and water (W_3 gram)	100.6	100.6	100.6	100.6	100.6
4	Weight of bottle full of water (W_4 gram)	91.85	91.85	91.85	91.85	91.85
5	Weight of dry soil $(W_2 - W_1)$ in gram	15	15.03	15.01	15.03	15.04
6	Weight of an equal volume of water [$(W_2 - W_1) - (W_3 - W_4)$]	6.25	6.25	6.25	6.25	6.25
7	Specific gravity (G) $\frac{(W_2-W_1)}{(W_2-W_1)-(W_3-W_4)}$	2.4	2.43	2.52	2.43	2.43
8	Average Specific Gravity	2.442				

b) Standard Proctor Test

The standard Proctor Test Results of the sample soil is given in tabulated form below:

Table 4.3 Standard Proctor Test

Sl No.	Dry Density (KN/m3)	Water Content (%)
1	14.97	5
2	17.47	10
3	19.09	20
4	18.45	25
5	18.06	30
6	16.78	35
7	15.01	40
8	11.19	45

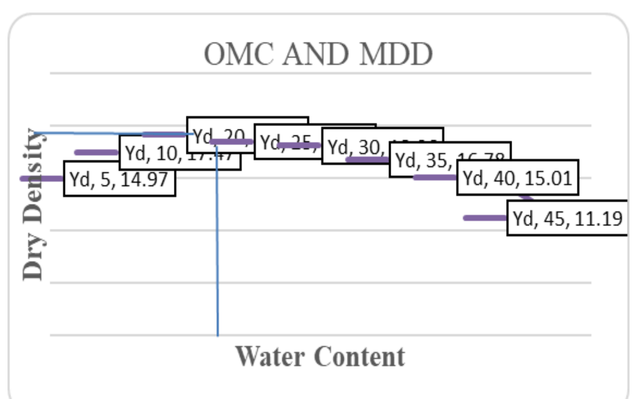

Fig 4.2: Dry Density and Water Content

From the above graph we found that for our sample the Maximum Dry Density (MDD) is 19.09 KN/m3 and Optimum Moisture Content (OMC) is 20%.

c) Consistency Limits

Consistency limits of the soil sample is presented in tabulate form below:

Table 4.4 Liquid Limit

Blows initial	Blows final	No. of blows	Water content (%)	Liquid limit (WL)	Avg. liquid limit(%)
66	160	94	35	40.34	
160	189	29	40	40.6	
189	204	15	42.5	40.44	
204	232	28	41	41.47	40.45
232	262	30	38.5	39.22	
262	288	26	42	42.17	
288	320	32	38	38.96	

Table 4.5 Plastic Limit

Trial No.	Plastic limit (%)	Average value of Plastic Limit
1	29	
2	30	
3	29.25	
4	31	30
5	30.5	
6	29.5	
7	30.75	

From above we obtained plastic limit of the sample is 30% and liquid limit is 40.45%. Shrinkage limit is 1.7% for the sample soil.

d) Tests on soil earthen blocks

Compressive and shear strength tests were conducted to evaluate the required properties of the earthen blocks. The test methods are already discussed in Chapter 4. Total of nine samples were tested, three samples for each type of blocks. It is given as below:

Table 4.6 Load Bearing Capacity and Compressive Strength of Ordinary Soil Blocks

Sample No.	Load Capacity(in KN)	Avg. Load Capacity(in KN)	Compressive Strength(in KN/m2)	Avg. Compressive Strength(in KN/m2)
1	6.98	7.12	1424.49	1453.75
2	7.24		1477.56	
3	7.15		1459.19	

Table 4.7 Load Bearing Capacity and Compressive Strength of Soil Blocks Modified by Coir Fibers

Sample No.	Load Capacity(in KN)	Avg. Load Capacity(in KN)	Compressive Strength(in KN/m2)	Avg. Compressive Strength(in KN/m2)
1	16	14.05	3265.31	2866.67
2	12.18		2485.72	
3	13.96		2848.98	

Table 4.8 Load Bearing Capacity and Compressive Strength of Soil Blocks Modified by Coir Fibers

Sample No.	Load Capacity(in KN)	Avg. Load Capacity(in KN)	Compressive Strength(in KN/m2)	Avg. Compressive Strength(in KN/m2)
1	27	27.86	5510.21	5685.72
2	28.96		5910.21	
3	27.62		5636.74	

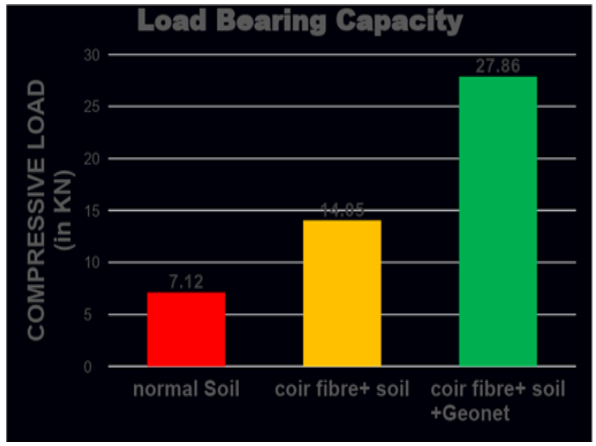

Fig 4.3: Load Bearing Capacity of Different Blocks

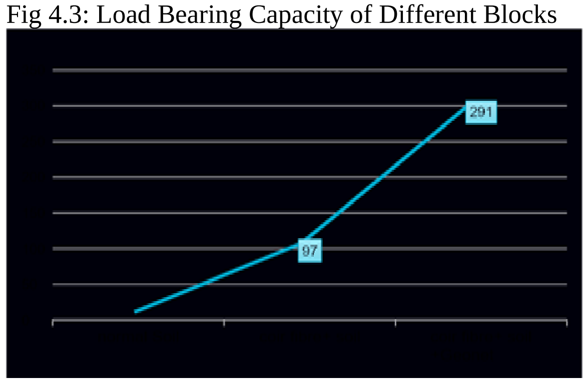

Fig 4.4: Percentage Increase in Compressive Strength

From the above tables and graphs it is seen that there is a significant increase in load bearing capacity and compressive strength. By using coir fibers and geo-net to modify the soil. From the Fig 5.3.2, it is seen that there is a 97% (relative to the strength of ordinary soil block of the same soil) increase in compressive strength for the soil blocks modified by coir fibers only. And soil blocks modified by coir fibers and geo-net exhibits 291% (relative to the strength of ordinary soil block of the same soil) increase in compressive strength. When it is compared with the blocks modified by coir fibers only it is observed that there is 199% increase in the compressive strength.

Table 4.9 Direct Shear Test Data for Soil Modified by Coir Fibers Only

Sl No.	Time elapsed (min)	Shearing displacement (no load)	Corrected area Ac= Ao(1-d/3)	Stress dial gauge reading (division)	Shear force (0.47 x5) Kg	Shear Stress =(6/4) Kg/Cm2
1	*2*	*3*	*4*	*5*	*6*	*7*
1	1	0.13	29.8193	8	3.76	0.126093
2	2	0.255	28.52055	10	4.7	0.164793
3	3	0.382	27.20102	-15	-7.05	-0.25918

Sl No.	Time elapsed (min)	Shearing displacement (0.5 kg)	Corrected area Ac=Ao (1-d/3)	Stress dial gauge reading (division)	Shear force (0.47 x5) Kg	Shear Stress =(6/4) Kg/Cm2
1	*2*	*3*	*4*	*5*	*6*	*7*
1	1	0.114	29.98554	12	5.64	0.188091
2	2	0.234	28.73874	15	7.05	0.245313
3	3	0.36	27.4296	17	7.99	0.291291
4	4	0.489	26.08929	18	8.46	0.324271
5	5	0.614	24.79054	19	8.93	0.360218
6	6	0.741	23.47101	20	9.4	0.400494
7	7	0.867	22.16187	21	9.87	0.44536

Sl No.	Time elapsed (min)	Shearing displacement (1 kg)	Corrected area Ac=Ao (1-d/3)	Stress dial gauge reading (division)	Shear force (0.47 x5) Kg	Shear Stress =(6/4) Kg/Cm2
1	*2*	*3*	*4*	*5*	*6*	*7*
1	1	0.112	30.00632	12	5.64	0.18796
2	2	0.237	28.70757	19	8.93	0.311068
3	3	0.365	27.37765	22	10.34	0.37768
4	4	0.493	26.04773	25	11.75	0.451095
5	5	0.619	24.73859	28	13.16	0.531962
6	6	0.745	23.42945	31	14.57	0.621867
7	7	0.87	22.1307	32	15.04	0.679599

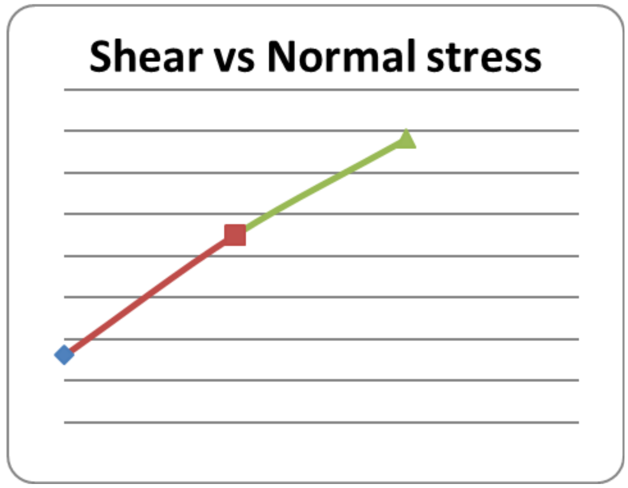

Fig 4.5: Shear Stress – Normal stress Graph for Soil plus Coir Fibers

Table 4.10 Direct Shear Test Data for Soil Modified by Coir Fibers and Geo-net

Sl No.	Time elapsed(min)	Shearing displacement (no load)	Corrected area Ac=Ao(1-d/3)	Stress dial gauge reading (division)	Shear force (0.47 x5) Kg	Shear Stress =(6/4) Kg/Cm2
1	*2*	*3*	*4*	*5*	*6*	*7*
1	1	0.117	29.95437	11	5.17	0.172596
2	2	0.242	28.65562	16	7.52	0.262427
3	3	0.361	27.41921	18.5	8.695	0.317113
4	4	0.49	26.0789	20	9.4	0.360445
5	5	0.615	24.78015	21	9.87	0.398303
6	6	0.735	23.53335	21.5	10.105	0.429391
7	7	0.85	22.3385	21.5	10.105	0.452358

Sl No	Time elapsed (min)	Shearing displacement (0.5 kg)	Corrected area Ac=Ao (1-d/3)	Stress dial gauge reading (division)	Shear force (0.47x5) Kg	Shear Stress =(6/4) Kg/Cm2
1	*2*	*3*	*4*	*5*	*6*	*7*
1	1	0.113	29.99593	22	10.34	0.344713
2	2	0.247	28.60367	28	13.16	0.460081
3	3	0.37	27.3257	31	14.57	0.533198
4	4	0.497	26.00617	34	15.98	0.61447
5	5	0.619	24.73859	35	16.45	0.664953
6	6	0.746	23.41906	36	16.92	0.722488

Sl No	Time elapse (min)	Shearing displacement (1kg)	Corrected area Ac=Ao(1-d/3)	Stress dial gauge reading (division)	Shear force (0.47x5) Kg	Shear Stress =(6/4) Kg/Cm2
1	*2*	*3*	*4*	*5*	*6*	*7*
1	1	0.11	30.0271	31	14.57	0.485228
2	2	0.24	28.6764	41	19.27	0.671981
3	3	0.36	27.4296	46.5	21.855	0.796767
4	4	0.49	26.0789	50	23.5	0.901112
5	5	0.62	24.7282	50.5	23.735	0.959835
6	6	0.744	23.43984	53	24.91	1.062721

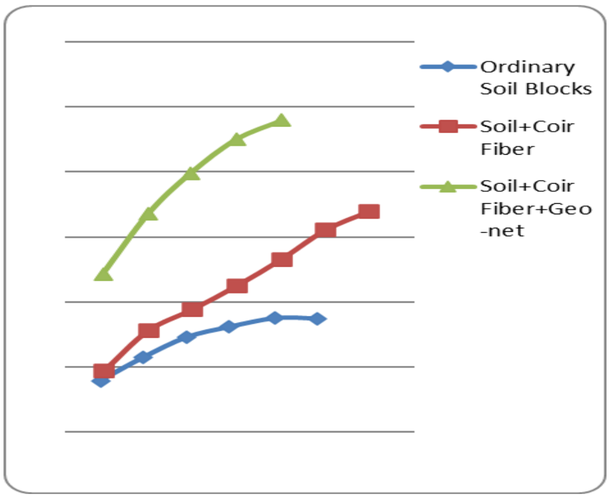

Fig 4.6: Comparison Between Shear stress and Shear Displacement of Each Type of Sample Under 1 kg Normal Stress

From above results it can be seen that there is a 194.28% increase in shear strength of the sample modified with coir fibers only, when compared with the shear strength of ordinary soil sample. When it is compared with the sample modified with coir fibers and geo-net it exhibits 305.7% increase in shearing strength. Sample modified with geo-net and coir fibers exhibits 157.35% more shearing resistance relative to the sample modified with coir fibers only.

V. CONCLUSIONS

From the results of laboratory investigation, the following conclusions are drawn:

a. Comparing ordinary rammed earth blocks with blocks modified with only coir fiber shows, 1.98 times increase in compressive strength and 1.96 times in shear strength.

b. Comparing ordinary rammed earth blocks with blocks modified with coir fiber and geo-net shows, 3.92 times increase in compressive strength and 3.06 times in shear strength.

c. It is also observed that these blocks have increased ductility. They undergo compression but are able to retain their forms in verge of failure. Fibers and geo-net also prevent form cracks. Where the ordinary blocks have very little soundness.

REFERENCE

[1] Arora K. R., (1988), Introductory Soil Engineering: Text Book, Nem Chand Jane (Prop), Standard Publishers Distributors, Nai Sarak, Delhi.
[2] Francisco R. A. Ziegler-Rivera etal. (2021): Acid copper sulfate solution (ACSS) like mine spills is mainly responsible for the effects in soils and sediment due to which we investigate the ACSS.
[3] HanifiBinici et al. (2008) : The results show that the basaltic pumice improve the sound insulation performance of fibre reinforced mud bricks.
[4] Hakan A. Nefeslioglu et al. (2013): On the geo-mechanical properties of claystones and mudstone collected from Firuzkoy area of Turkey.
[5] IS: 2720 Part-XIII (1972), Direct Shear Test, BIS, New Delhi.
[6] IS:2720-Part V (1970), Determination of Liquid and Plastic Limits, BIS, New Delhi.
[7] IS:2720-Part IV (1975), Grain Size Analysis, BIS, New Delhi.
[8] IS:2720-Part II (1973), Determination of Water Content, BIS, New Delhi.
[9] IS:2720- Part XXIX (1975), Determination of Dry Density of Soils.
[10] Ime Akanyeti (2020): Performance of bricks made by waste materials.
[11] M. S. Moka et al. (2010): Improved performance of compacted soil by using Geo-fibers. Meriem Saidi et al. (2018): Effect of soil modifications on earthen buildings.
[12] Mahgoub M. Salih et al. (2019): Modification of soil by chicken feather fibres(CFF) & sugarcane bagasse fibres(SBF)
[13] N. Lingeshwaran et al. (2020): Performance analysis declared the efficiency of Reinforced masonry walls to be higher than the masonry

walls without reinforcement under both axial and seismic loads.
[14] S. Ajouguim et al. (2020): Mechanical and thermal properties of the earthen blocks reinforced by alfa fibers extracted from Moroccan Alfa plant.
[15] S. Muthu Lakshmi et al. (2020): Improve the strength characteristics of clays sand using fly ash and geonet. Electromagnetic reflectors. IEEETrans. PlasmaSci. [Online].21(3).pp. 876-880.