International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 04 | April - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

IMPROVING THE ENGINEERING PROPERTIES OF CLAYEY SOIL USING SILICA FUME AND SISAL FIBER

Mohmmad Hassan Cho[1], Anoop Sharma[2]

[1]*PG student, Dept. of Civil Engineering, Sri Sai College of Engineering& Technology, Badhani, Punjab, India*
[2]*Assistant Professor, Dept. of Civil Engineering, Sri Sai College Of Engineering& Technology, Badhani, Punjab, India*
Anoopsharma777r@gmail.com

---***---

Abstract - Building on soft soils continues to be a challenge for civil engineers in the modern world, despite the rapid development of infrastructure projects and advancements in construction technology. They exhibit a large volumetric change upon contact with water, which is the cause of their limited bearing capacity. Various stabilization strategies can be used to handle the soft clay's shear strength issue. In this experiment, sisal fibers and silica fumes were added in different amounts to the clay soil in order to determine the ideal moisture content and strength parameters for reaching the maximum dry density of the soil. By adjusting the amount of sisal fiber for each amount of silica fume, the Unconfined Compressive Strength (UCS) test has been used to examine the strength of both natural clay and clay modified with silica fume (6%, 12%, 18%) and sisal fibers (0.5%, 1.0%, 1.5%) separately, as well as the combination of all the materials. Using a small compaction device, standard proctor test was used to determine the ideal moisture content and maximum dry density. According to the test results, the maximum dry density falls with increasing silica fume content likewise, the maximum dry density increases with increasing sisal fiber content. The addition of 12% silica fume and 2.0% sisal fiber to the clay sample results in a maximum strength when taking the strength parameter into account.

***Key Words*:** Compaction test, CBR, UCS, Silica fume, Sisal Fiber

INTRODUCTION

The highest unconsolidated portion of the earth that is naturally occurring in the universe is called soil. It is created when rocks break down in the presence of naturally occurring elements like heat, wind, rain, and snow. It is the least expensive building material and widely accessible. Due of its extremely varied composition and features, it is a challenging material. The location and geography of the soil affect its properties. The characteristics of the soil should align with the specifications of an engineering structure's design for safer construction. In this work, the geotechnical engineer is crucial in determining whether or not the soil satisfies the structural criteria. Building engineering structures on unstable ground carries a significant risk.

Frequently, the soil that is readily available is unsuitable for building. The primary characteristics of soil that we have to deal with are strength, permeability, and stability on slopes. In order to investigate the engineering behavior of soil, we must address issues related to slopes, earth dams, foundations, retaining structures, and pavement building.

2. Literature Review

Manjunath K.R. et al. (2013) studied the effect of sisal fiber on compaction and strength characteristics of black cotton soil treated with lime. They reported that for a particular fiber percentage, the MDD of stabilized soil increases and OMC decreases. The maximum dry density and OMC of sisal fiber reinforced soil increased with 3% lime. 3% of lime content and 0.75% sisal fiber were considered as optimum percentage for black cotton soil to increase the California bearing ratio value.

SavithaA.L. et al. (2013) conducted compaction tests and UCS tests on Black Cotton soil using coarse and fine fly ash. They varied the percentage of flyash from 5% to 25% with increase of 5% at a time. Curing was done for 1,7,14,28 days. They reported that the strength obtained by fine Sugarcane Bagasse Ashwas 25% more than that of coarse fly ash.On increasing water contentupto 30%, the dry density decreases and if water content is increased further the dry density decreases gradually.The MDD was 1.35 g/cc for 5% Sugarcane Bagasse Ashmixed with 95% soil and lowest density was 0.6g/cc for 30% Sugarcane Bagasse Ashmixed with 70% soil.

Agrawal M.L. et al. (2013) performed compaction tests and CBR test on black cotton soil. They varied the percentage of flyash from 10% to 50% with increase of 10% at a time.They investigated that the MDD increases with increment in Sugarcane Bagasse Ashup to 20% , and with more addition it decreases. The increase in CBR value and dry density is maximum for 30% Sugarcane Bagasse Ashmixture with black cotton soil. On increasing percentage of fly ash, there is decrease in thethe liquid limit of black cotton soil, resulting in reduced swelling of soil.

Ruprai B.S. et al (2013) conducted compaction test and California bearing ratio test on black cotton soil. They used varying percentages of Sugarcane Bagasse Ashi.e. 10, 20, 30, 40, 50% and observed the effect of Sugarcane Bagasse Ashon moisture –density relationship and CBR value of soil. They reported that as compared to other mixes the CBR value is higher for 20% fly ash.Moreover the dry density was also more at 20% Sugarcane Bagasse Ashcontent.

Yanbin Li et al. (2014) performed compaction test and triaxial shear test on silty clay. They used 0.5%, 1%, 1.5% sisal fiber with lengths 5mm, 10mm and 15 mm. They reported that the stress increased with increase in strain when 1.0% fiber content is taken and they observed no decrease in stress when the strain exceeded 1.0%.They reported that silty clay reinforced with sisal fiber has 20% more strength than non-reinforced clay when 1.0% fiber content of length 10 mm is considered.

Kumar R. et al. (2014) studied the effect of sisal fibers on the UCS value of bentonite. He reported that there can be an increase in the UCS value of bentonite by adding lime, phosphogypsum and sisal fibers. The highest UCS value was obtained at 8% lime, 8% phosphogypsum and 1% sisal fibers. UCS value increased with increment in fiber from 0.5 to 2% fiber.

Abadi et al. (2014) conducted compaction test and California bearing ratio test on clay. He varied the percentage of flyash from 5% to 25% with increase of 5% at a time. He reported that the MDD of clay increased with increment in ash till 15%, then decreased to 1.53 at 20% ash. The OMC decreased until 15 %,then after that it started to increase. CBR value reduces slightly when soil ash mixture contains more than 15% ash.

Swarup J. et al.(2015) performed compaction tests and CBR tests on the black cotton soil. They used sisal fiber

(0.25%, 0.5%, 0.75%, 1%, 2%, 3%), NaOH (3%, 6%, 9%, 12%,15%) and flyash 20% by weight of dry soil. They concluded that optimum value of NaOH is 9%, 12N. Normal soil matrix gives the maximum CBR values at nearly 11% of fiber content but due to this stabilization technique,the maximum amount of CBR value can be attained at less amount of fiber content i.e. at 0.2%.

Bharathan et al., (2017) studied the effect of silica fume and cement on clayey soil . The fixed ratio of cement 10% added by varying the percentage of silica fume from 5% to 20% at an interval of 5% with clayey soil. The results showed that the increase in silica fume upto 15% increases both unconfined compressive strength and California bearing ratio. Further increase of the silica fume will reduce both UCS and CBR value.

Kawther et al., (2018) studied the Remediation of Clayey Soil Using Silica Fume. Different percentage of silica fume added with soil sample are 0, 3, 5 and 7%. Tests like Specific gravity, compaction characteristics, swell and swell pressure, CBR and compressive strength tests had been conducted on the prepared and modified soils. Results clarified that by increasing silica fume content leads to decrease the plasticity index and liquid limit while causes an increase in plastic limit and optimum water contents . The maximum dry unit weight values also decreases. The compressive shear strength, California Bearing Ratio (CBR), swell and swell pressure is also improved by using silica fume.

Sharanakumar et al., (2018) The sisal fiber was collected from Tokyo Engineering Corporation Private Limited, Coimbatore (Tamilnadu).Soil stabilization is done with the addition of sisal fiber with varying percentages of sisal fiber are 0.2%, 0.5%, 0.9% and 1.2% with varying lengths of sisal fiber are 3cm, 3.2cm and 3.4cm length at the interval of 0.2cm.For knowing the properties of soil laboratory tests are to be done. They are Atterberg's limits, Light compaction test, unconfined compressive strength test, Specific gravity test, California bearing ratio test, Moisture content test and Sieve analysis test.

S.M Kavitha et al., (2019) Geotechnical engineers face various problems while designing foundation because of clayey soil due to poor bearing capacity and excessive settlement. So, we rectify that with various engineering works but in this project we choose fibers for improving soil parameters, this method is cost-effective and eco-friendly one. The clay sample was collected from Devakottai, Tamil Nadu, and India. Sisal, polypropylene, and hybrid of these two fibers were used for soil stabilization. The sisal fiber was mixed 0 .1%, 0.2%, 0.3% and 0.4% by weight of the soil samples. Similarly, polypropylene fiber was mixed 0.5%, 1%, 1.5% and 2% by weight of the soil samples and hybrid fiber mixed soil samples randomly distributed.

Vishal Kumar et al., (2022) In the field of civil engineering, stabilization of soil is a procedure to improve and enhance the engineering properties of soil in such a manner that it can withstand heavy loads without any failure. In current work, the behaviour of soil after adding the rice husk ash (fixed proportion 10%) and sisal fibre (varying proportion 0.5%, 0.75% and 1%; varying length 20 mm and 40mm) was studied at different proportions and then different soil properties like, OMC, MDD, CBR value and UCS values were determined.

3. Materials

3.1 SOIL

Source of soil

The soil used in this study was obtained from village. As per IS classification of soil, the soil used is low compressibility silt. The soil properties are given in the table as under:

Table no. 1 Properties of soil used in the study

S.No.	Properties	Result
1.	Liquid limit (%)	33
2.	Plastic limit (%)	21
3.	Plasticity Index (%)	12
4.	Specific Gravity	2.55
5.	Maximum Dry Density (KN/m^3)	17.10
6.	Optimum Moisture Content (%)	14.25
7.	Soil Classification	CI (Intermediate Compressive Clay)
8.	CBR (%) (soaked)	2.40
9.	CBR (%) (Unsoaked)	4.30
9.	UCS ($kN/m^{2)}$)	290

3.2 SILICA FUME

Source of SILICA FUME

The silica fume used in this study for stabilizing clayey soil was procured from Mahalaxmi Chemicals Enterprises, Delhi. The density of silica fume is 2.0–2.5 mg/m3, and its bulk density is 0.3–0.5 mg/m3. Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide and it is produced in electric furnace. The raw materials are quartz, coal and woodchips. The ash that results from this process is collected and sold as silica fume.

Table 2: The properties of silica fume are given below;

S.No	Parameters	Mass (%)
01.	Silica as SiO_2,	85-95%
03.	Lime as CaO	0.8-2%
04.	Magnesia as MgO	1-2%
05.	Alumina as Al_2O_3	1-3%
06.	Iron Oxide as Fe_2O_3	0.5-1%
07.	Density , kg/m^3	$600kg/m^3$

3.3 SISAL FIBRE

Source of sisal fiber

The sisal fiber used in this study was obtained from Jindaram Exports, Sirsa. Sisal is a natural fiber having greater tensile strength and can be used as an effective reinforcing material in soil stabilization. Sisal Fiber length 40mm is used in this study. The properties and composition of sisal fiber are discussed in table no. 3 and 4

Table 3:- Properties of Sisal Fiber

No	operty	lue
	lour	iite
	ecific Gravity (Kg/m^3)	70
	ater Absorption (%)	)
	ngth of fiber (mm)	
	ameter of sisal fiber (mm)	
	nsile Strength(MPa)	7
	odulus of elasticity (GPa)	

Table 4:- Chemical Composition of Sisal Fiber

; .No	mponent	rcentage
	llulose	.5
	micelluloses	.1
	gnin	)
	ctin	}
	axes	;
	ater Soluble Matter	7

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

Table no. 5: MDD and OMC for soil– Silica Fume– sisal fiber mix

oportion Soil : Silica me: Sisal fiber	DD N/m^3)	MC ;)
0:00:00	.10	.25
:12:1.0	.9	.8
.5:12:1.5	.9	.5
:12:2.0	.4	.1

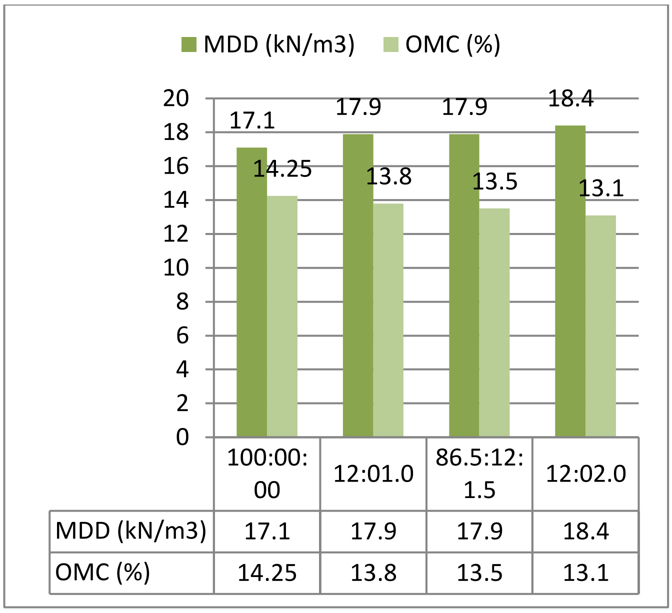

Fig:-1 variations b/w MDD and OMC of Silica Fume, Sisal Fiber & soil with different proportions

Table 6: Results of UCS of Silica Fume and Sisal Fiber Mix with Soil

oportion Soil : Silica fume: ;al fiber	Curing Period ays)	UCS (kN/m²)
0:00:00		0
:12:1.0		5
.5:12:1.5		0
:12:2.0		0

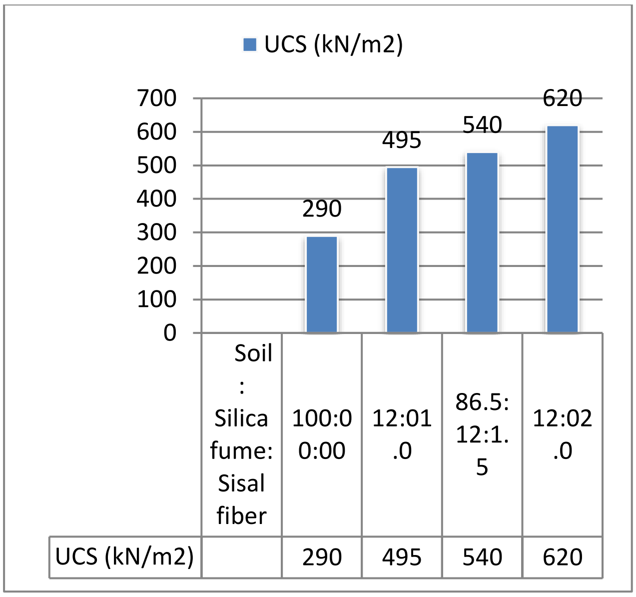

Fig:-2 Variations b/w UCS Values of Clayey soil, Silica Fume and Sisal Fiber with different proportions

Table 5: Results of CBR of Silica Fume and Sisal Fiber Mix with Soil

portion Soil : Silica fume: l fiber	CBR (%) (Soaked)	CBR (%) (Unsoaked)
:00:00	2.40	4.30
12:1.0	4.5	7.2
;:12:1.5	5.3	8.5
12:2.0	5.9	9.4

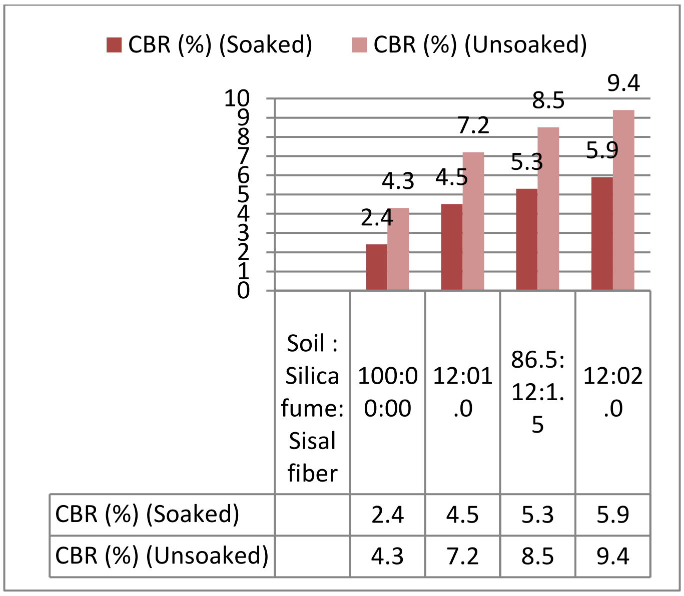

Fig:-3 Variations b/w CBR Values of Clayey soil, Silica Fume and Sisal Fiber with different proportions

5. DISCUSSIONS

STANDARD PROCTOR TEST:

- There is an also decrease of OMC from 14.25 to 13.1% and increase of MDD from 17.10 to 18.4% when the percentages of Sisal Fiber vary from 1.0%, 1.5% and 2.0% and Silica fume is fixed at 12%.
- With Silica fume kept constant at 12% MDD increases with an addition of Sisal Fibre content in soil and Silica fume mix. The reason behind such behaviour is silica fume is lighter in weight and it has high water absorption properties because of the presence of silica oxide and hence OMC increases with the increase of silica fume content.

CBR TEST:

- The CBR value of virgin soil is 2.40 and it increase to 2.45 times when silica fume 12% and Sisal Fiber 2.0% is added to virgin soil. This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essentials particle present in the soil.

UCS TEST:

- UCS value of virgin soil enhances fundamentally with expansion of silica fume contents. The UCS value increment from 290kN/m^2 to 530kN/m^2 with expansion of silica fume upto 18% in the wake of curing time of 7 days. The expansion in U.C.S. value might be increases with addition of Silica Fume and Sisal Fiber
- The UCS values of virgin soil also improve considerably with expansion of silica fume 12% and Sisal Fiber 2.0%. The value increases from 290kN/m^2 to 620kN/m^2 with addition of silica fume and Sisal Fiber.

6. CONCLUSIONS

Following conclusions can be inferred on the basis of the experiments performed:

1. The silica fume changes compaction parameters of clayey soil. The maximum dry unit weight decreases with the increase of the SF content, while optimum moisture content increases with increasing SF content.
2. Sisal fiber on the other hand is a cheaply available material which can be added to soil in less quantity to make big changes in its strength parameters.
3. The addition of the fixed quantity of silica fume 12% with changing the content of Sisal Fiber decrease the value of optimum moisture content and increases the value of maximum dry density.
4. The C.B.R value increases with increase of Sisal Fiber along with fixed quantity of silica fume. It increased 2.45 times from the untreated soil.
5. The optimum value of Sisal Fiber and silica fume required for soil stabilization is 2.0% and 12% by weight of soil respectively.
6. Unconfined compressive strength increases with increase of quantity of Sisal Fiber and with fixed quantity of silica fume.
7. Silica fume value of unconfined compressive strength is increased 2.54 times from the untreated soil.
8. Hence, the addition of Sisal Fiber and silica fume makes the soil mixes durable, economical and effective for soil stabilization process if these two materials are easily available near to the site.

References

- Santhi Krishna K. and Sayida M.K "Behaviour of Black Cotton Soil Reinforced with Sisal Fiber" Proceedings of 10th National Conference on Technological Trends (NCTT09), Kerala, India, 2009
- Brooks, R. M., "Soil Stabilization with Sugarcane Bagasse Ashand Rice Husk Ash" International Journal of Research and Reviews in Applied Sciences, vol.1, no. 3, pp. 209-217, 2009.
- Ayyappan, S., Hemalatha, M.K. and Sundaram M., "Investigation of Engineering Behavior of Soil, Polypropylene Fibers and Fly Ash-Mixtures for Road Construction", International Journal of Environmental Science and Development, 1(2), pp.171, 2010.
- Aigbodion, V. S., S. B. Hassan, T. Ause, and G. B. Nyior. "Potential utilization of solid waste (Sugarcane Bagasse Ash)." Journal of minerals and materials characterization and engineering 9(01), pp. 67, 2010.
- Amu, O.O., Ogunniyi, S.A. and Oladeji, O.O., 2011. Geotechnical properties of lateritic soil stabilized with sugarcane straw ash. American journal of scientific and industrial research, 2(2), pp.323-331.
- Saravanan, R., Thomas, R.S. and Joseph, M., "A Study on Soil Stabilization of Clay Soil using Fly Ash. "International Journal Research. Civil Enggineering Architecture Design, 1, pp.33-37, 2013.
- Kawade, U. R., V. R. Rathi, and Vaishali D. Girge. "Effect of Use of Sugarcane Bagasse Ash on Strength of Concrete." International Journal of Innovative Research in Science, Engineering and Technology 2(7), pp. 2997-3000, 2013.
- Wubshet M. Sugarcane Bagasse Ash as a sub-grade soil stabilizing material. Addis Ababa Institute of Technology. 2013.
- Kharade, A.S., Suryavanshi, V.V., Gujar, B.S. and Deshmukh, R.R., "Waste Product Sugarcane Bagasse Ash from Sugar Industry can be Used as Stabilizing Material for Expansive Soils". International Journal of Research in Engineering and Technology, 3(3), pp.506-512, 2014.
- Jiesheng, Liu, Zhang, Juan, and Xia Lin. "Deformation and Strength Characteristics of Sisal Fibrous Soil." EJGE, 19, 2014.
- Kumar, S., Dutta, R. K., & Mohanty, B. "Potential of bentonite-lime-mix modified with phosphogypsum and reinforced with sisal fibers", Periodica Polytechnica Civil Engineering, 59(2), pp. 143-154, 2015.
- Das, Arindam, and Sabyasachi Roy. "Effect of Expansive Soil on Foundation and its Remedies." In National Conference on Emerging Technology and Applied Sciences (NCETAS) 15th-16th Feb, pp. 92-95. 2014.
- Butt, Wajid Ali, B. A. Mir, and J. N. Jha. "Strength Behavior of Clayey Soil Reinforced with Human hair as a Natural Fiber", Geotechnical and Geological Engineering, 34(1), pp. 411-417, 2016.
- Abhijit, S. and Aruna, T. "Effect of Ground Granulated Blast Furnace Slag(GGBS) and Sisal Fibers on Black Cotton Soil", International Journal of Innovative Research in Science, Engineering and Technology, 4(7), pp. 5409-5417, 2015.
- Alhassan, Musa, and Alhaji Mohammed Mustapha. "Improvement of Deficient Soils in Nigeria using Sugarcane Bagasse Ash- A Review", In Proceeding of 17th International Conference on Civil and Building Engineering, Dubai, pp.1040-1049, 2015.
- Sandyarani, Dr.Vageesha S Mathada and Sharanakumar. "Stabilization of black cotton soil by using Sisal fiber", International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 08 | Aug 2018.
- Ahmed Khan, Mohd Fahiem Tahir and Er.

Tripti Goyal, “Study on engineering properties of soil using bagasse ash and sisal fiber shazad”, International Research Journal of Engineering and Technology (IRJET), Volume: 06 Issue: 03 | Mar 2019.

- Vishal Rana and Prof. Vinod Kumar Sonthwal, “Improving the Engineering Properties of Soil Using Sisal Fibre with Rice Husk Ash,” International Journal for Research in Applied Science & Engineering Technology (IJRASET), ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538, Volume 10 Issue V May 2022.
- Adarsh Minhas, Veena Uma Devi (2016), *soil stabilization of alluvial soil by using marble powder*, International Journal of Civil Engineering and Technology (IJCIET) Vol. 7, Issue pp. 87–92, Article ID: IJCIET ISSN: 0976-6316.
- Akshaya Kumar Sabat and Radhikesh P. Nanda, *“Effect of marble dust on strength and durability of Rice husk ash stabilised expansive soil”*, International Journal Of Civil And Structural Engineering, Volume 1, No 4, 2011, 939-948.
- Altug saygili (2015) *Use of Waste Marble Dust for Stabilization of Clayey Soil*’ ISSN 1392–1320 materials science (Medziagotyra).
- Asskar Janalizadeh Choobbasti , Saman Soleimani Kutanaei (2017) *Microstructure characteristics of cement-stabilized sandy soil using nanosilica*, Journal of Rock Mechanics and Geotechnical Engineering.
- Baser O (2009), “*Stabilization of Expansive Soils Using Waste Marble Dust”,* Master of Science Thesis, Submitted to Civil Engineering Department, Middle East, Technical University.
- Chhaya Negi, R.K. Yadav, A.K. Singhai (2013) *Effect of Silica Fume on Index Properties of Black Cotton Soil* International Journal of Scientific & Engineering Research, Volume 4, Issue 8, ISSN 2229-5518.
- F. Yilmaz and M. Yurdakul Bayburt (2016) *Evaluation of Marble Dust for Soil Stabilization* DOI: 10.12693/APhysPolA.132.710 .
- Gyaneshwar Singh Uchariya Rohit Arya M.k.Trivedi (2016) *Stabilization of Clay by using Wood Ash and Fly Ash* IJSRD Vol.4, ISSN : 2321-0613.
- Khan, S.A. (2005). *Stabilization of soil using marble industry waste*, Proceedings of the 6th International Conference on ground improvement techniques.
- Parte Shyam Singh and Yadav (2014*) Effect Of Marble Dust On Index Properties Of Black Cotton Soil* IJERST Vol. 3, ISSN 2319-5991.
- R.P. Arora, N.K. Ameta, Kapil K. Samar And K.L. Samdani (2014) *Improvement of engineering characteristics of locally available soil mass by use of marble dust* ISSN-2230-9284 .
- R.Bharathan, A.Giridharan, P.Saranya (2017) *Soil Stabilization Using Silica Fume and Cement* SSRG International Journal of Civil Engineering – (ICCREST’17) - Special Issue- ISSN: 2348 – 8352.
- Sreekumar. V.Babu, Mary Rebekah Sharmila (2017) *Soil Stabilisation Using Marble Dust* International Journal Of Civil Engineering And Technology (IJCIET) Vol. 8 Pp. 1706-1713, Article Id: Ijciet_08_04_192 ISSN : 0976-6316.
- Singh, R.B. and Khanna, P. (1999). *Studies on a reinforced system for utilization of thermal power plant waste fly ash, fly ash disposal and deposition*: Beyond 2000 AD, Narosa Publishing House, New Delhi (INDIA).
- Sachin N. Bhavsar and Ankit J. Patel,(2014) “*Behavior of Black Cotton Soil after Stabilization with Marble Powder”,* International Journal of

Science and Research (IJSR). Volume 3, Issue 11 (November2014) pg 200-206 and Volume 3 Issue 12 (December 2014) pg 769-772