Study on the Compaction Characteristics of Soil and Marble Dust Composite as a Potential Green Building Material

D. Sabari[1]; Dr.M. Ramalakshmi[2*]

[1]Research Scholar, Department of Civil Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India.

[1]dampurusabari17@saveetha.com

[2*]Project Guide, Department of Civil Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India.

[2*]ramalakshmim.sse@saveetha.com

Abstract

The aim of the study is to evaluate the effects of adding the waste marble dust to soil on the compaction characteristics of the soil. Standard Proctor test is conducted for two groups of samples (Group 1 without marble dust group N = 17; group 2: Soil with marble dust N = 17). The test results show that the optimum moisture content (OMC) of soil decreases and the maximum dry density (MDD) increases due to the addition of marble dust with the soil. There is a significance difference between the two groups of soil as the value of p<0.05. Soil with marble dust gets compacted more than the soil without marble dust. Thus the marble dust can be used as an additive material so as to improve the compaction characteristics of the soil.

1. Introduction

Marble dust is the waste product generated during cutting and polishing of marble stones. It is one of the industry generated waste materials, the disposal of which would cause pollution issues. Rather than being disposed of as waste, it can be recycled and innovatively used along with soil as one of the green building approaches in earthen embankments for the construction of dams, bridges and roads (Shruthi and Binil 2016) (Yadav 2019). Studying the modifications in the compaction characteristics of the soil when marble dust is added to it. The improvement of clayey soil utilizing marble residue is being studied by many to analyse the suitability of this measure for the locally

available soils. The soil in the campus of Saveetha School of Engineering is red soil. The bearing capacity of soils is predominantly governed by its density. If the soil's density is more, consequently the bearing capacity will also be more for that soil (Neeladharan et al. 2018) (Mishra and Arora 2019). Hence in this study, the density of the soil is aimed to be increased through the addition of marble dust. By studying the variation in the compaction characteristics (Ali, Khan, and Shah 2014) optimum amounts of marble dust (Kushwah and Gupta 2017) required for achieving the better compaction can be obtained.

The effectiveness of marble dust as a stabilization material for clays was studied ((Saygili 2015) (Priyanka and Raj Priyanka 2018). The maximum percentage of replacement studied was 30%. It was observed that addition of marble dust in the soil effectively reduced the swell potential of expansive clays. In the previous studies (Gautam, Sharma, and Kaushik 2018); (Tak, Sharma, and Grover 2018; Deepak and Magandeep 2019), the optimum moisture content (OMC) decreased and maximum dry density (MDD) increased as a result of adding the marble dust with soil. Further addition of coir fibre along with marble dust, resulted in further decreases and increases in the OMC and MDD respectively. It was concluded that addition of marble dust with soils can be an economic and efficient ground improvement technique for stabilization of soils. In engineering projects dealing with weak soils, partial replacement of soil with marble dust can lead to foundation designs with shallow foundations in place of costly and time consuming deep/raft foundations. The reverse trends in OMC and MDD due to marble dust addition were also observed (Minhas and Devi 2016) (Yilmaz and Yurdakul 2017). They studied the effect of replacing the alluvial soil partially with marble dust. The OMC was observed to increase with increasing percentages of marble dust. Whereas the MDD of soil reduced when marble dust was added. In the study, many parameters of the soil were evaluated in detail. Hence it can be considered as one of the major contributions in the present study topic.

Previously our team has a rich experience in working on various research projects across multiple disciplines (Sathish and Karthick 2020; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020). Now the growing trend in this area motivated us to pursue this project.

The compaction characteristics and the engineering properties of red soil can be improved by adding marble dust. The study on the improvement of compaction characteristics of red sandy clay

soil could not be found in the literature. The present study aims to add the behaviour of red sandy clay soil with marble dust to the existing knowledge about marble dust as a stabilizing material.

2. Materials and Methods

The soil samples taken for the present study were collected at a depth of 1m from the college campus of Saveetha School of Engineering, Thandalam, Chennai. The collected soil samples were disturbed samples. Marble dust, which is used as the replacement material in the present study, was collected from "sacistha granite, Chennai". Tests were conducted on the collected soil samples to obtain their index properties (Table 1). Then marble dust was added in different percentages to the soil samples to study the resulting changes in the compaction characteristics. The soil tests were carried out in the Soil Mechanics lab of Saveetha school of engineering. Initially two groups of samples were tested: Group 1 - soil without marble dust; Group 2 - soil with 5% marble dust. Number of samples per group was calculated by using "clinical c" software. Sample size for each group was calculated by using the mean standard deviation values obtained from the study by ((Khuntia et al. 2015). The values of threshold limit, g power, and confidence interval were 0.05, 80% and 95% respectively and the sample size required was estimated to be 17.

Table 1 - Properties of soil and marble dust. As the uniformity coefficient is more than 4 for both soil and marble dust, both are uniformly graded materials. The effective size of marble dust is smaller than that of the soil taken for study.

Sl. No	Properties	Soil	Marble dust
1	Effective Size, D10 (mm)	0.33	0.22
2	D30 (mm)	1	1.5
3	D60 (mm)	1.7	0.8
4	Coefficient of curvature, Cc	1.782	1.93
5	Coefficient of uniformity, Cu	5.151	6.81
6	Specific gravity	2.65	2.98

About 1250 g of soil was mixed with different trial water contents and were filled with hammer compaction into the standard Proctor moulds of diameter 10 cm and height 10.7 cm. The soil was compacted in three layers by giving 25 hammer blows/each layer with standard Proctor hammer. Then the collar is removed and the soil surface is trimmed and the weight of the compacted soil is measured. Knowing the volume of the mould, the wet or bulk density (ρ_b) of the soil sample is

calculated. The dry density (ρ_d) is calculated from the wet density and moisture content (m). Similarly tests were conducted for group 2 soil by mixing 63 g of marble dust with 1187 g of soil. The soil and marble dust were mixed well and the mixture was compacted into Proctor mould.

Totally for 34 samples, the statistical analysis was carried out using SPSS software. The percentage of marble dust was the independent variable. The OMC and the MDD were the dependent variables in the statistical analyses.

3. Results

The marble dust appears to decrease the OMC and increase the MDD (Table 2 and Fig. 1). The results of the 34 samples were input in SPSS software and the results of the statistical analysis are given in Table 3. The bar graphs showing the mean and standard deviation values of the two soil groups are given in Fig. 2 (a) and (b) respectively. The statistical parameters (Table 4) also indicate that the difference between the two groups appears to be significant. The standard deviation values of OMC and MDD appear to be much less for the 17 samples considered. Hence as a preliminary study, the tests were further continued for higher percentages of marble dust namely 10%, 15% and 20% (Fig. 3 and Table 5). As the percentage of marble dust increases, the OMC appears to continuously decrease while the MDD appears to continuously increase (Fig. 4 and Table 6).

Table 2 - Moisture contents and bulk density and dry density values for the soil with and without marble dust. Group 2 Soil with marble dust has lesser OMC (11%) and higher MDD (2.1 g/cc)

Soil			Soil + 5% MD		
m (%)	ρ_b (g/cc)	ρ_d (g/cc)	m (%)	ρ_b (g/cc)	ρ_d (g/cc)
5	1.52	1.45	5	1.92	1.83
7	1.95	1.82	7	2.00	1.87
9	2.04	1.87	9	2.13	1.95
11	2.25	2.03	11	2.33	2.10
13	2.33	2.06	13	2.13	1.89
15	1.88	1.64	15	1.87	1.63

Fig. 1 - Compaction curves plotted with moisture content in X axis and dry density in Y axis (a) soil without marble dust has its peak at a higher moisture content (13%) (b) soil with 5% marble dust has its peak at a lower moisture content (11%)

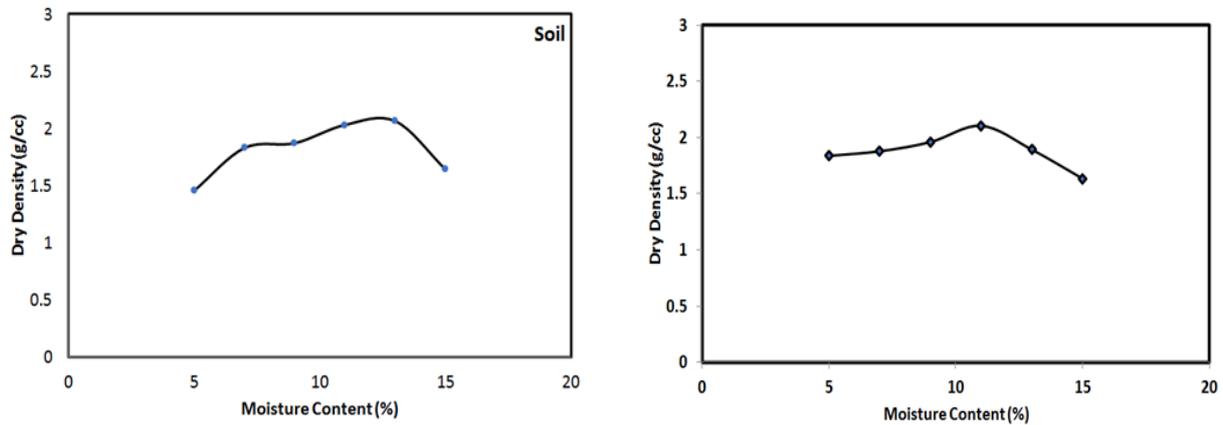(a)   (b)

Table 3 - Comparison of OMC and MDD (Mean and Standard error of mean) for soils with and without marble dust. The OMC decreases by 13% and MDD increases by 1.8% when 5% marble dust is added.

	Sample	N	Mean	Std. Deviation	Std.Error Mean
OMC	0.00% MD	17	13.00	.00000[a]	.00000
	5.00% MD	17	11.00	.00000[a]	.00000
MDD	0.00% MD	17	2.0661	.05521	.01301
	5.00% MD	17	2.1044	.08431	.01987

Fig. 2 - Bar chart comparing the mean +/- 1 SD of (a) optimum moisture content and (b) maximum dry density. There is a significant difference between the two groups p<0.05 (Independent Sample T Test). X Axis: Soil vs Soil + Marble dust, Y axis: Mean +/- 1 Standard Deviation
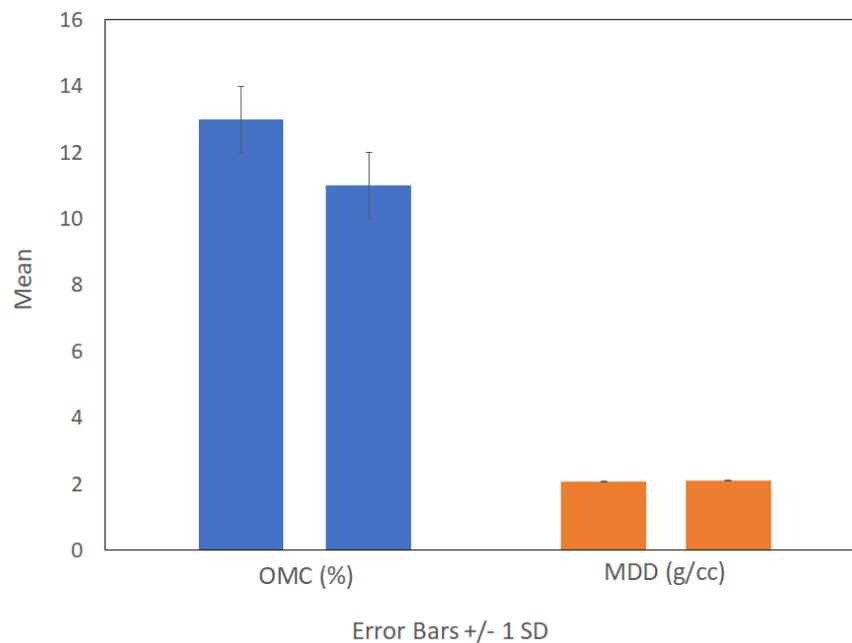
Table 4 - The mean, standard deviation and significance difference of MDD for soil with and without marble dust. There is a significance difference between the two groups since p<0.05 (Independent Sample T Test)

Levene's Test for Equality of variance		t-test for equality of means							
F	Sig.	t	df	Sig (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence interval of the difference		
							Lower	Upper	
1.557	.221	-36.975	34	.000	-.87833	.02375	-.92651	-.83006	
		-36.975	29.316	.000	-.87833	.02375	-.92689	-.8232	

Fig. 3 - Compaction curves plotted with moisture content in X axis and dry density in Y axis (a) soil with 10% marble dust (b) soil with 15% marble dust (c) soil with 20% marble dust. For soil with 20% marble dust the MDD is the highest and OMC is the lowest
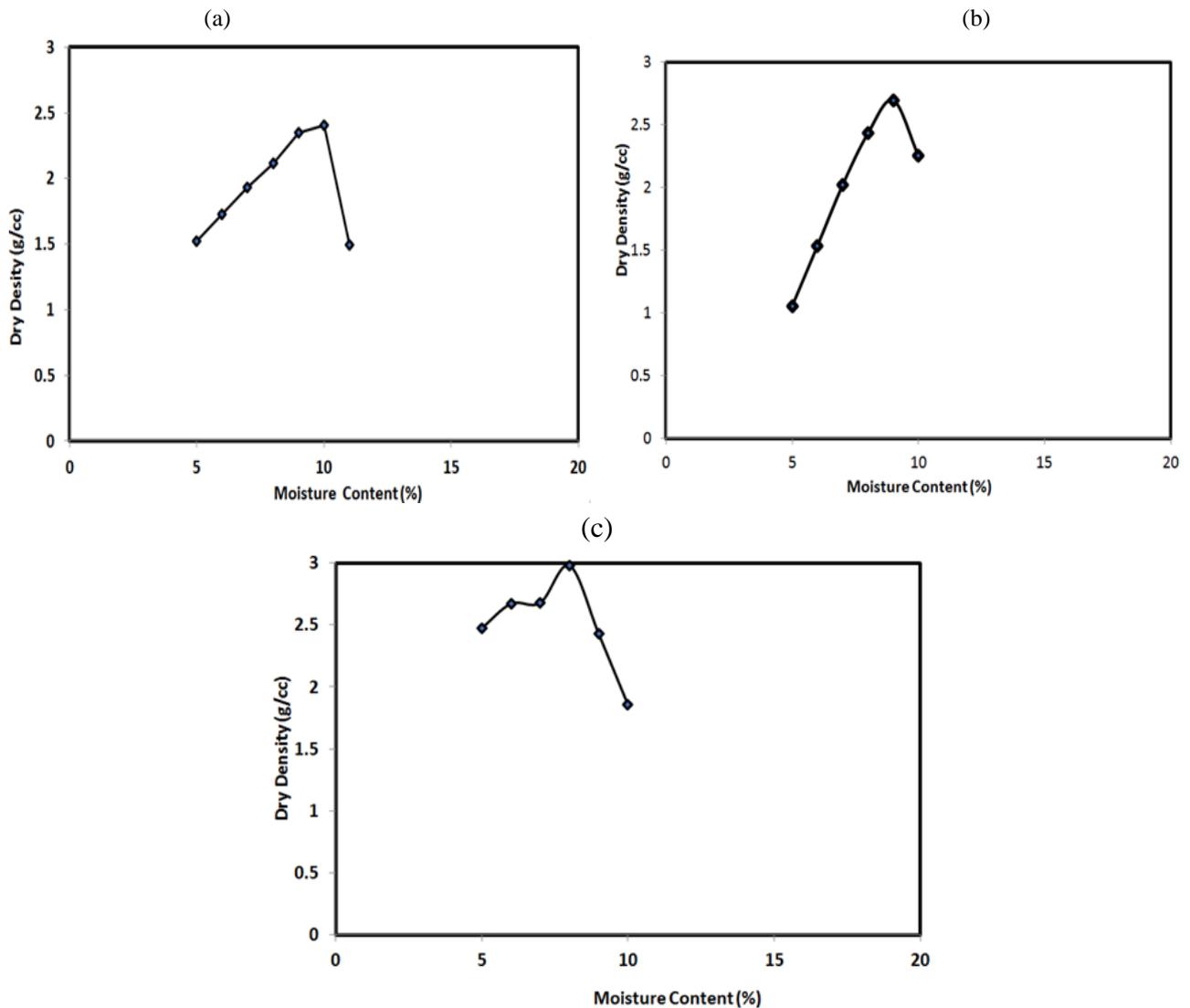
Table 5 - Water contents and density values for different soil groups. Soil with 20% Marble dust has has higher MDD (2.97 g/cc) and lower OMC (8%)

Soil + 10% MD			Soil + 15% MD			Soil + 20% MD		
w (%)	ρ_b (g/cc)	ρ_d (g/cc)	w (%)	ρ_b (g/cc)	ρ_d (g/cc)	w (%)	ρ_b (g/cc)	ρ_d (g/cc)
5	1.60	1.52	5	1.10	1.05	5	2.59	2.47
6	1.83	1.72	6	1.62	1.53	6	2.83	2.67
7	2.06	1.93	7	2.16	2.02	7	2.86	2.67
8	2.28	2.11	8	2.62	2.43	8	3.21	2.97
9	2.55	2.34	9	2.93	2.69	9	2.64	2.42
10	2.64	2.40	10	2.47	2.25	10	2.04	1.85
11	1.65	1.49	-	-	-	-	-	-

Fig. 4 - Influence of percentage of marble dust on (a) optimum moisture content (OMC), (b) maximum dry density (MDD). With increasing marble dust percentage, the OMC continuously decreases while the MDD continuously increases.
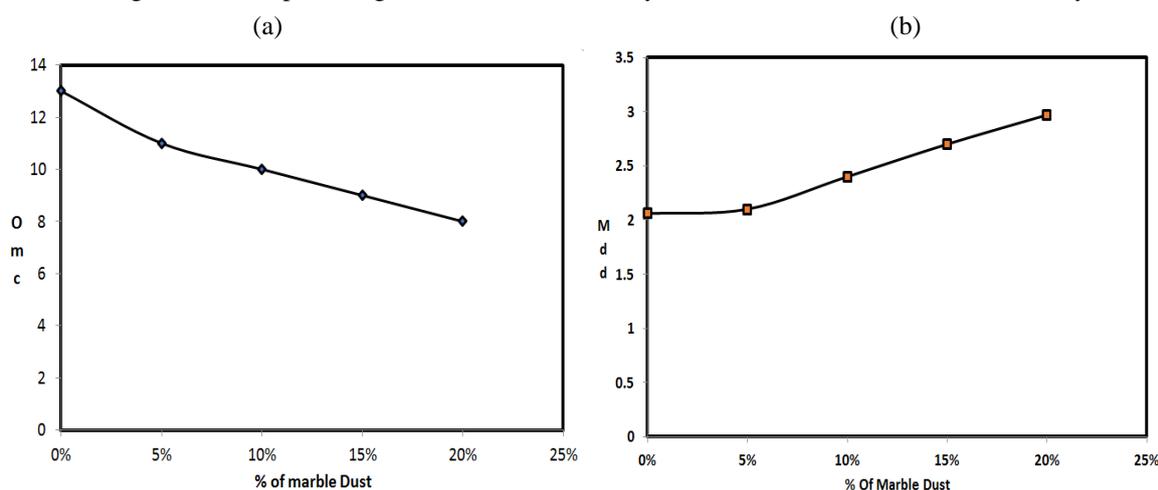

(a)

(b)

Table 6 - OMC and MDD values for different soil groups. As the % of marble dust increases, the OMC decreases (from 13% to 8%) while MDD increases (from 2.06 g/cc to 2.97 g/cc)

Sl. No	% Marble dust	OMC (%)	MDD (g/cc)
1	0%	13	2.06
2	5%	11	2.1
3	10%	10	2.4
4	15%	9	2.7
5	20%	8	2.97

4. Discussion

The soil group with marble dust gets compacted to a better extent than the soil group without marble dust (Table 2 and Fig. 1). Hence marble addition to the soil leads to a soil composite with improved compaction characteristics. Also the significance value p (Table 4) is less than 0.05, there is a significant difference in the behaviour of the two groups of soil considered. The marble dust being a

finer material, when it is added to the coarse grained soil, the smaller marble dust particles can occupy the voids in the soil and increase its density. This can be attributed to the reason why the MDD increases with the incorporation of marble dust in soil. Similar results were obtained by (Gautam, Sharma, and Kaushik 2018) and (Ali, Khan, and Shah 2014). (Bhavsar and Patel 2014) studied the characteristics of black cotton soil with and without marble dust. Addition of marble dust reduced the OMC but increased the MDD in the same trend that was observed in the present study.

The reverse effects were also observed in few studies (i.e.) the OMC increased and MDD decreased when marble dust was added to the soils that were considered in their studies. The addition of marble dust with soil increased the optimum moisture content and reduced the maximum dry density (Minhas and Devi 2016). The soil considered in the aforementioned study is an alluvial soil, which is smaller in grain size than the marble dust. Therefore the marble dust increased the amount of moisture needed for maximum compaction when added to such alluvial soils. Thus the effects of marble dust on soils depend primarily on the type of soil to which it is added to. The gradation characteristics of marble dust, the method of compaction are the secondary factors which would influence the OMC and MDD achieved.

Our institution is passionate about high quality evidence based research and has excelled in various fields ((Vijayashree Priyadharsini 2019; Ezhilarasan, Apoorva, and Ashok Vardhan 2019; Ramesh et al. 2018; Mathew et al. 2020; Sridharan et al. 2019; Pc, Marimuthu, and Devadoss 2018; Ramadurai et al. 2019). We hope this study adds to this rich legacy.

The marble dust addition causes whether any increase or decrease in MDD and MCC largely depends on the soil gradation characteristics. Therefore the presented results are applicable for the soil types considered in the present study. The modification in the settlement or compressibility characteristics of the soil can be taken as the further study.

5. Conclusion

The inclusion of marble dust in soil (Group 2) results in higher MDD. The increase in the maximum dry density indicates increased bearing capacities of the soil. The moisture content, at which maximum compaction is arrived, decreases. It signifies the effect of cohesive action of marble dust in enabling the soil to get compacted well even with less water added to it. Thus it can be stated that the soil and marble dust composite can be innovatively used as an effective green building material.

Declarations

Conflict of Interests: No conflict of interest in this manuscript.

Author Contribution

Author SD involved in data collection, experimental study and manuscript writing. Author RM involved in conceptualization, guidance and critical review of manuscript.

Acknowledgements

References

Ali, R., H. Khan, and A.A. Shah. 2014. "Expansive Soil Stabilization Using Marble Dust and Bagasse Ash." *International Journal of Science and Research* 3 (6): 2812–16.

Bhavsar, Sachin N., and Ankit J. Patel. 2014. "Behaviour of Black Cotton Soil after Stabilization with Marble Powder." *International Journal of Science and Research* 3 (12): 769–72.

Deepak, Kumar, and Bishnoi Magandeep. 2019. "A Review Paper on Experimental Study on Stabilization of Soil Subgrade by Adding Stone Dust." *International Journal of Trend in Scientific Research and Development* 3 (4): 1063–64.

Ezhilarasan, Devaraj, Velluru S. Apoorva, and Nandhigam Ashok Vardhan. 2019. "Syzygium Cumini Extract Induced Reactive Oxygen Species-Mediated Apoptosis in Human Oral Squamous Carcinoma Cells." *Journal of Oral Pathology & Medicine: Official Publication of the International Association of Oral Pathologists and the American Academy of Oral Pathology* 48 (2): 115–21.

Gautam, Nidhi, J.K. Sharma, and N.P. Kaushik. 2018. "Stabilisation of Expansive Soil Using Marble Dust and Coir Fiber." In *Proceedings of IGC 2018.* IISc Bangalore.

http://www.igs.org.in:8080/portal/igc-proceedings/igc-2018-bengaluru-proceedings/Theme05/TH-05-34.pdf.

Gheena, S., and D. Ezhilarasan. 2019. "Syringic Acid Triggers Reactive Oxygen Species-Mediated Cytotoxicity in HepG2 Cells." *Human & Experimental Toxicology* 38 (6): 694–702.

Jose, Jerry, Ajitha, and Haripriya Subbaiyan. 2020. "Different Treatment Modalities Followed by Dental Practitioners for Ellis Class 2 Fracture – A Questionnaire-Based Survey." *The Open Dentistry Journal* 14 (1): 59–65.

Ke, Yang, Mohammed Saleh Al Aboody, Wael Alturaiki, Suliman A. Alsagaby, Faiz Abdulaziz Alfaiz, Vishnu Priya Veeraraghavan, and Suresh Mickymaray. 2019. "Photosynthesized Gold Nanoparticles from Catharanthus Roseus Induces Caspase-Mediated Apoptosis in Cervical Cancer Cells (HeLa)." *Artificial Cells, Nanomedicine, and Biotechnology* 47 (1): 1938–46.

Khuntia, Sunil, Hassan Mujtaba, Chittaranjan Patra, Nagaratnam Sivakugan Khalid Farooq, and Braja M. Das. 2015. "Prediction of Compaction Parameters of Coarse Grained Soil Using Multivariate Adaptive Regression Splines (MARS)." *International Journal of Geotechnical Engineering* 9 (1): 79–88.

Krishnaswamy, Haribabu, Sivaprakash Muthukrishnan, Sathish Thanikodi, Godwin Arockiaraj Antony, and Vijayan Venkatraman. 2020. "Investigation of Air Conditioning Temperature Variation by Modifying the Structure of Passenger Car Using Computational Fluid Dynamics." *Thermal Science* 24 (1 Part B): 495–98.

Kushwah, Shivendra Singh, and Shilpi Gupta. 2017. "Effect of Marble Slurry Dust and Lime Stabilization on Geotechnical Properties of Fine Sand." *International Journal of Research in Engineering and Technology* 6 (10): 62–72.

Malli Sureshbabu, Nivedhitha, Kathiravan Selvarasu, Jayanth Kumar V, Mahalakshmi Nandakumar, and Deepak Selvam. 2019. "Concentrated Growth Factors as an Ingenious Biomaterial in Regeneration of Bony Defects after Periapical Surgery: A Report of Two Cases." *Case Reports in Dentistry* 2019 (January): 7046203.

Mathew, M.G., S.R. Samuel, A.J. Soni, and K.B. Roopa. 2020. "Evaluation of Adhesion of Streptococcus Mutans, Plaque Accumulation on Zirconia and Stainless Steel Crowns, and Surrounding Gingival Inflammation in Primary …." *Clinical Oral Investigations*. https://link.springer.com/article/10.1007/s00784-020-03204-9

Mehta, Meenu, Deeksha, Devesh Tewari, Gaurav Gupta, Rajendra Awasthi, Harjeet Singh, Parijat Pandey, et al. 2019. "Oligonucleotide Therapy: An Emerging Focus Area for Drug Delivery in Chronic Inflammatory Respiratory Diseases." *Chemico-Biological Interactions* 308 (August): 206–15.

Minhas, Adarsh, and Veena Uma Devi. 2016. "Soil Stabilization of Alluvial Soil by Using Marble Powder." *International Journal of Civil Engineering and Technology* 7 (5): 87–92.

Mishra, Priyanka, and V.K. Arora. 2019. "Stabilization of Silty Soil with Marble Dust and Sugarcane Bagasse Ash." *Lecture Notes in Civil Engineering* 32: 51–58.

Muthukrishnan, Sivaprakash, Haribabu Krishnaswamy, Sathish Thanikodi, Dinesh Sundaresan, and Vijayan Venkatraman. 2020. "Support Vector Machine for Modelling and Simulation of Heat Exchangers." *Thermal Science* 24 (1 Part B): 499–503.

Neeladharan, C., P. Sathish, A. Nandhini, R. Priya, I. Sadiqua Fathima, and J. Srimathi. 2018. "Stabilization of Soil by Using Marble Dust with Sodium Silicate as Binder." *International Journal of Advanced Research Trends in Engineering and Technology* 5 (5): 45–49.

Pc, J., T. Marimuthu, and P. Devadoss. 2018. "Prevalence and Measurement of Anterior Loop of the Mandibular Canal Using CBCT: A Cross Sectional Study." *Clinical Implant Dentistry and Related Research*. https://europepmc.org/article/med/29624863.

Priyanka, T. Raj, and T. Raj Priyanka. 2018. "Stabilization of Black Cotton Soil with Marble Dust." *International Journal for Research in Applied Science and Engineering Technology* 6 (5): 2057–60.

Ramadurai, Neeraja, Deepa Gurunathan, A. Victor Samuel, Emg Subramanian, and Steven J. L. Rodrigues. 2019. "Effectiveness of 2% Articaine as an Anesthetic Agent in Children: Randomized Controlled Trial." *Clinical Oral Investigations* 23 (9): 3543–50.

Ramesh, Asha, Sheeja Varghese, Nadathur D. Jayakumar, and Sankari Malaiappan. 2018. "Comparative Estimation of Sulfiredoxin Levels between Chronic Periodontitis and Healthy Patients - A Case-Control Study." *Journal of Periodontology* 89 (10): 1241–48.

Samuel, Melvin S., Jayanta Bhattacharya, Sankalp Raj, Needhidasan Santhanam, Hemant Singh, and N. D. Pradeep Singh. 2019. "Efficient Removal of Chromium(VI) from Aqueous Solution Using Chitosan Grafted Graphene Oxide (CS-GO) Nanocomposite." *International Journal of Biological Macromolecules* 121 (January): 285–92.

Samuel, Srinivasan Raj, Shashidhar Acharya, and Jeevika Chandrasekar Rao. 2020. "School Interventions-Based Prevention of Early-Childhood Caries among 3-5-Year-Old Children from Very Low Socioeconomic Status: Two-Year Randomized Trial." *Journal of Public Health Dentistry* 80 (1): 51–60.

Sathish, T., and S. Karthick. 2020. "Wear Behaviour Analysis on Aluminium Alloy 7050 with Reinforced SiC through Taguchi Approach." *Journal of Japan Research Institute for Advanced Copper-Base Materials and Technologies* 9 (3): 3481–87.

Saygili, Altug. 2015. "Use of Waste Marble Dust for Stabilization of Clayey Soil." *Materials Science* 21 (4): 601–6.

Sharma, Parvarish, Meenu Mehta, Daljeet Singh Dhanjal, Simran Kaur, Gaurav Gupta, Harjeet Singh, Lakshmi Thangavelu, et al. 2019. "Emerging Trends in the Novel Drug Delivery Approaches for the Treatment of Lung Cancer." *Chemico-Biological Interactions* 309 (August): 108720.

Shruthi, Johnson, and Gopinath Binil. 2016. "A Study on the Swell Behaviour of Expansive Clays Reinforced with Saw Dust, Coir Pith Marble Dust." *International Journal of Engineering Research and Technology* 5 (9): 565–70.

Sridharan, Gokul, Pratibha Ramani, Sangeeta Patankar, and Rajagopalan Vijayaraghavan. 2019. "Evaluation of Salivary Metabolomics in Oral Leukoplakia and Oral Squamous Cell Carcinoma." *Journal of Oral Pathology & Medicine: Official Publication of the International Association of Oral Pathologists and the American Academy of Oral Pathology* 48 (4): 299–306.

Tak, Dayanand, Jitendra Kumar Sharma, and K. S. Grover. 2018. "Use of Kota Stone Powder to Improve Engineering Properties of Black Cotton Soil." In *Proceedings of IGC 2018*.

Varghese, Sheeja Saji, Asha Ramesh, and Deepak Nallaswamy Veeraiyan. 2019. "Blended Module-Based Teaching in Biostatistics and Research Methodology: A Retrospective Study with Postgraduate Dental Students." *Journal of Dental Education* 83 (4): 445–50.

Venu, Harish, V. Dhana Raju, and Lingesan Subramani. 2019. "Combined Effect of Influence of Nano Additives, Combustion Chamber Geometry and Injection Timing in a DI Diesel Engine Fuelled with Ternary (diesel-Biodiesel-Ethanol) Blends." *Energy* 174 (May): 386–406.

Venu, Harish, Lingesan Subramani, and V. Dhana Raju. 2019. "Emission Reduction in a DI Diesel Engine Using Exhaust Gas Recirculation (EGR) of Palm Biodiesel Blended with TiO2 Nano Additives." *Renewable Energy* 140 (September): 245–63.

Vignesh, R., Ditto Sharmin, C. Vishnu Rekha, Sankar Annamalai, and Parisa Norouzi Baghkomeh. 2019. "Management of Complicated Crown-Root Fracture by Extra-Oral Fragment Reattachment and Intentional Reimplantation with 2 Years Review." *Contemporary Clinical Dentistry* 10 (2): 397–401.

Vijayakumar Jain, S., M.R. Muthusekhar, M. F. Baig, P. Senthilnathan, S. Loganathan, P.U. Abdul Wahab, M. Madhulakshmi, and Yogaen Vohra. 2019. "Evaluation of Three-Dimensional Changes in Pharyngeal Airway Following Isolated Lefort One Osteotomy for the Correction of Vertical Maxillary Excess: A Prospective Study." *Journal of Maxillofacial and Oral Surgery* 18 (1): 139–46.

Vijayashree Priyadharsini, Jayaseelan. 2019. "In Silico Validation of the Non-Antibiotic Drugs Acetaminophen and Ibuprofen as Antibacterial Agents against Red Complex Pathogens." *Journal of Periodontology* 90 (12): 1441–48.

Yadav, Amendra Prasad. 2019. "A Comparative Study of Waste Foundry Sand and Marble Dust for Stabilization of Subgrade Soil." *International Journal for Research in Applied Science and Engineering Technology*. https://doi.org/10.22214/ijraset.2019.4222.

Yilmaz, F., and M. Yurdakul. 2017. "Evaluation of Marble Dust for Soil Stabilization." *Acta Physica Polonica A* 132 (3): 710–11.