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Using Fine Silica Sand and Granite Powder Waste to Control Free Swelling Behavior of High Expansive Soil

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Abstract

Many researchers have been interested in studying the effect of adding local natural materials or construction waste on the properties of poor subgrade soil. However, changes in size and strength of expansive soils can cause extensive damage to the geotechnical infrastructure. This damage is often repeatable and latent in the long term, and is a critical issue in highway subgrade engineering. This paper examines the effect of adding both Fine Silica Sand (FSS) and Granite Cutting Powder Waste (GPW) materials on the welling characteristics of expansive soils. Atterberg limits, free swell index, and rate of swell of the mixtures were used as a key to assess properties of a group of expansive soil samples after adding different percentages of the mentioned materials. The rates of additions were 10%, 20%, 30%, 40%, 50%, 60 and 70% of the weight of the soil samples. The test results showed that FSS and GPW significantly affect the expansive soil properties. However, adding 70% of both FSS and GPW reduced the swelling index from 58.3% to 6.6% and from 58.3% to 11% after 7 days of curing, respectively. This study suggests that the Fine Silica Sand and Granite Powder Waste can be used as stabilizers for expansive highly plastic soils.

Keywords: high expansive soils, bentonite, silica sand, granite waste, swell, stabilization

1. Introduction

Expansive soils can be characterized by its potential for volume changes as well as can be characterized by its high strength when dry, very low strength when wet, wide and deep shrinkage cracks in the dry season, and high plasticity.

Expansive soils always cause problems because when they are used as foundation material for engineering structures such as subgrade for pavement structures, the latter are liable to suffer some distress and damage due to the excessive volume changes of the soil profiles. These changes occur as a result of an increase or a decrease in moisture content.

Expansive soils engineering properties need to be improved to make these soils suitable for construction purposes. Geotechnical properties of expansive soils are improved by different techniques. The problematic soil can be removed and replaced by a better-quality material or can be treated using mechanical or chemical stabilization. The most effective and economical methods to prevent volume changes of an expansive soils is through the use of additives materials.

The need for economic soil stabilizers materials and economic waste disposal cost has led to intense global research towards economic utilization of locally available materials and industry wastes for engineering purposes.

Recent trend in research works in the field of construction materials focused more on the use of potentially materials that are cheap and locally available such as industry wastes as additives materials for improvement of the soils properties such as (Monica et al. [1], Talal Masoud et al. [2], Gupta Chayanet al [3], Sabat, [4], Sabat and Nanda, [5], Ravi Shanker Mishra, M. K. Gupta [6], Palaniappan and Stalin, [7], Ene and Okagbue, [8], These research works carried out to satisfy the safe and environmental disposal of industry waste, and the need for better and cost effective construction materials.

Considering the important of utilization of locally available materials as an alternative soil stabilization material, the purpose of the experimental work in this study is to investigate the effects of addition of locally granite cutting powder waste and locally fine silica sand materials on Atterberg limits, and free swell characteristics of expansive soils.

2. Materials and Test Program

This experimental study aims to investigate the effects of the addition of fine silica sand and granite cutting powder waste on swell characteristics of expansive soils and, to investigate the rate of swell of an expansive soil stabilized with fine silica sand and granite cutting powder waste.

A. Expansive soil (Bentonite)

In this study commercial bentonite clay was used to prepare a potentially expansive soil. Bentonite can be considered as a good grade of high swelling soil. The commercial bentonite used in this study without any treatment because it comes in the form of fine powder.

B. Silica Sand

Fine silica sand is locally available in Jordan and financially cheap. Fine silica sand was passed through No. 40 sieve before usage.

C. Granite Cutting Powder Waste

Locally available granite cutting powder waste was used. The important characteristic of granite cutting powder waste as an additive material is the percentage passing through No. 40 sieve. Since all particles of granite cutting powder waste pass through No. 40 sieve, all of granite cutting powder waste particles and bentonite can be used in Atterberg limit and free swelling tests without further sieving.

D. Index Properties of Expansive Soil-Sand and Expansive Soil- Granite Powder Waste Mixtures

To mix the sand and granite powder waste with expansive soils, both materials were first initially dried. A number of samples were prepared by mixing the expansive soils with 10%, 25%, 50%, 60%, and 70%, of fine silica sand and granite cutting powder waste. The prepared samples were then tested to determine the Atterberg limits and the swell properties. The measured index properties are liquid limit (LL), plastic limit (PL), and plasticity index (PI). To study the swelling property of the soils samples, the simplest free swell index test was conducted. Free swell index of expansive soil indicates the swell potential of a soil.

3. Test Results and Discussions

A. Effect of Silica Sand and Granite Powder Waste on Expansive Soils Index Properties

Index properties include consistency limits (LL, PL, and PI = LL-PL) of the all proposed soils samples are summarized in Table 1.The relationship between plasticity index and swell behavior of soil has been identified by several researchers; in this study the relationship suggested by O’neıll and Poormaayed [10] is used.

Figure 1 to Figure 6 shows the relationship between Atterberg limits and percentage of fine silica sand and granite powder waste in graphical form.

Table 1. Relationships between plasticity index (PI) and swell potential (O’neıll and Poormaayed) [10]

Swelling Potential	Plasticity Index
Low	<25
Medium	25-35
High	>35

Table 2. Proposed Expansive Soils Sample Properties and Classification Based on Plasticity Index Properties

Percentage of Addition	**Liquid Limit (%)**		**Plastic Limit (%)**		**Plasticity Index PI**		**O'neıll and Poormaayed [10] classification**	
	Fine Silica Sand (FSS)	GranitePowderWaste (GPW)	Fine Silica Sand (FSS)	Granite Powder Waste (GPW)	Fine Silica Sand (FSS)	Granite Powder Waste (GPW)	Fine Silica Sand (FSS)	*Granite Powder Waste (GPW)*
0	342.5		74.67		267.83		*High*	
10	315.8	332	66.43	67.03	249.37	264.97	*High*	
20	306.25	320	65.39	66.03	240.86	253.97	*High*	
30	287.5	303	57.93	59.66	229.57	243.34	*High*	
40	245.4	271	52	54.4	193.4	216.6	*High*	
50	215	252	49.23	51.37	165.77	201.63	*High*	
60	190	216.6	47.57	48.1	142.43	168.5	*High*	
70	170	185.2	44.88	46.7	124.12	138.5	*High*	

Table 3. Percent Changes in Liquid Limit, Plastic Limit, and Plasticity Index Values

Percentage of Addition	**% Change in Liquid Limit**		**% Change in Plastic Limit**		**% Change in Plasticity Index (PI)**	
	Fine Silica Sand (FSS)	Granite Powder Waste (GPW)	Fine Silica Sand (FSS)	Granite Powder Waste (GPW)	Fine Silica Sand (FSS)	Granite Powder Waste (GPW)
0	0.00		0.00		0.00	
10	-7.7	-3	-11	-10.2	-6.9	1.1 -
20	-10.5	-6.6	-12.4	11.6 -	-10.1	5.2 -
30	-16.1	-11.5	-22.4	20.1 -	14.3 -	9.1 -
40	-28.4	-21.2	-30.4	-27.1	27.8 -	19.1 -
50	-37.2	-26.4	-34.1	31.2 -	38.1 -	24.7 -
60	- 44.5	-36.8	-36.3	35.6 -	46.8 -	37.1 -
70	-50.4	-45.9	-39.9	37.5 -	53.7 -	48.3 -

*(-) Shows the decrease in values

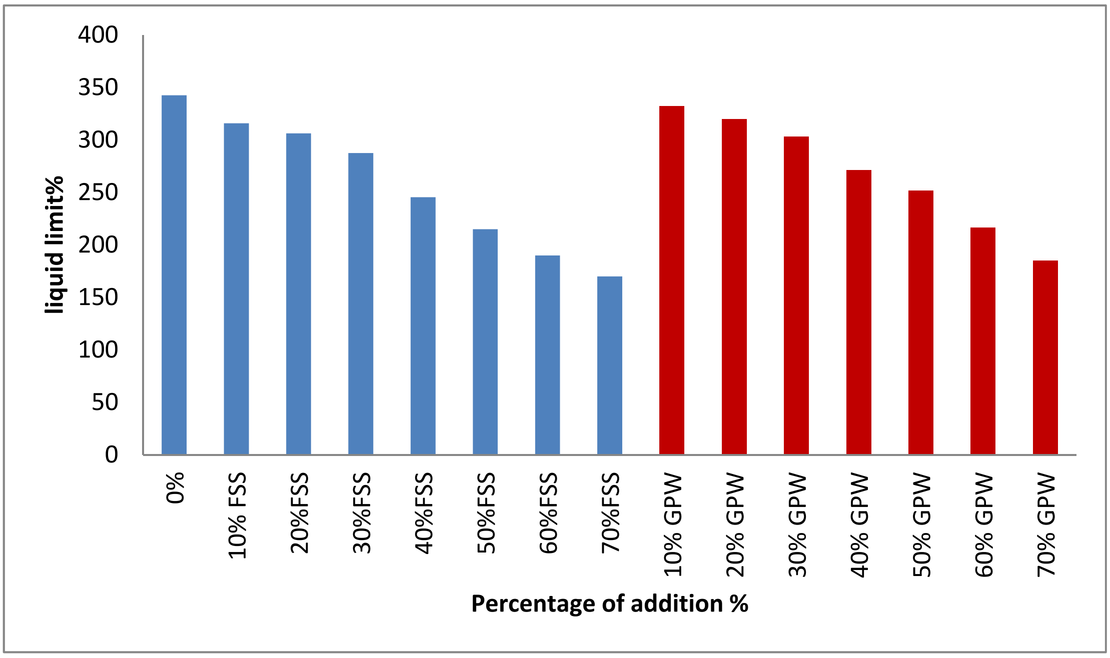

Figure 1. Effects of Fine Silica Sand and Granite Waste Powder Addition on the Liquid Limit

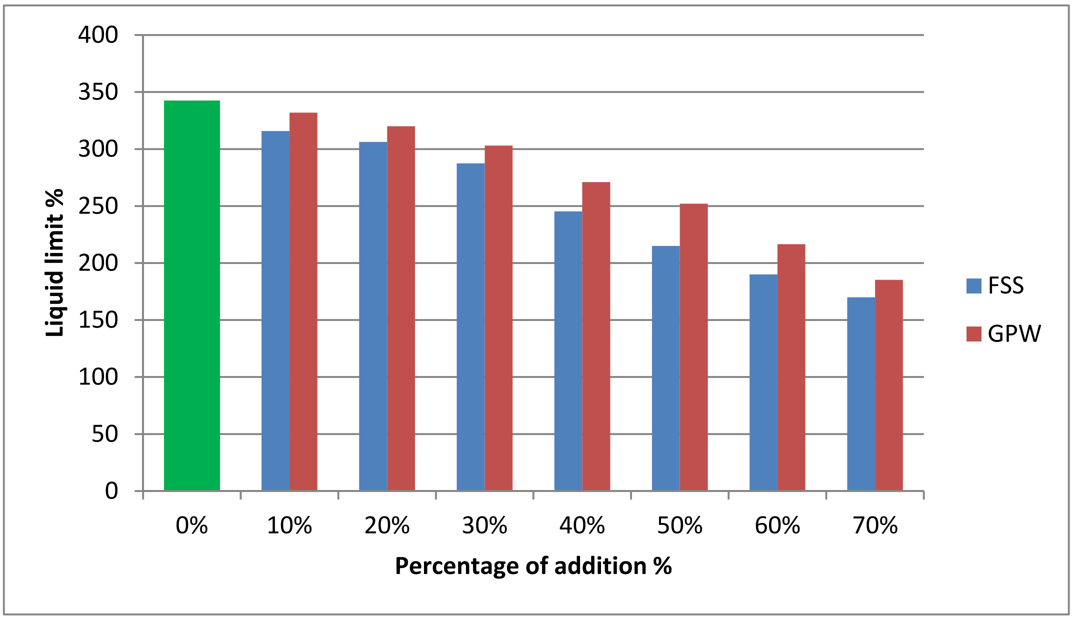

Figure 2. Effects of Fine Silica Sand versus Effects of Granite Waste Powder on the Liquid Limit

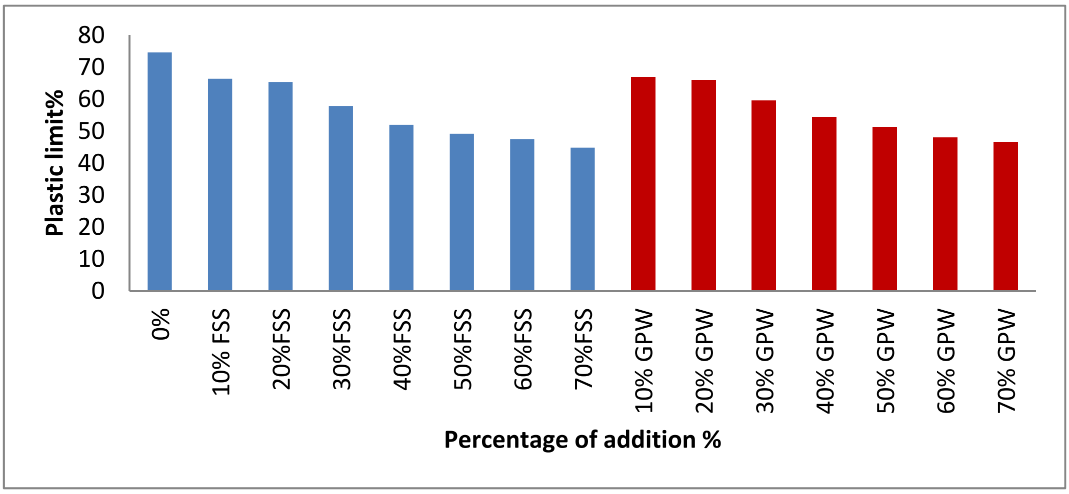

Figure 3. Effects of Fine Silica Sand and Granite Waste Powder Addition on the Plastic Limit

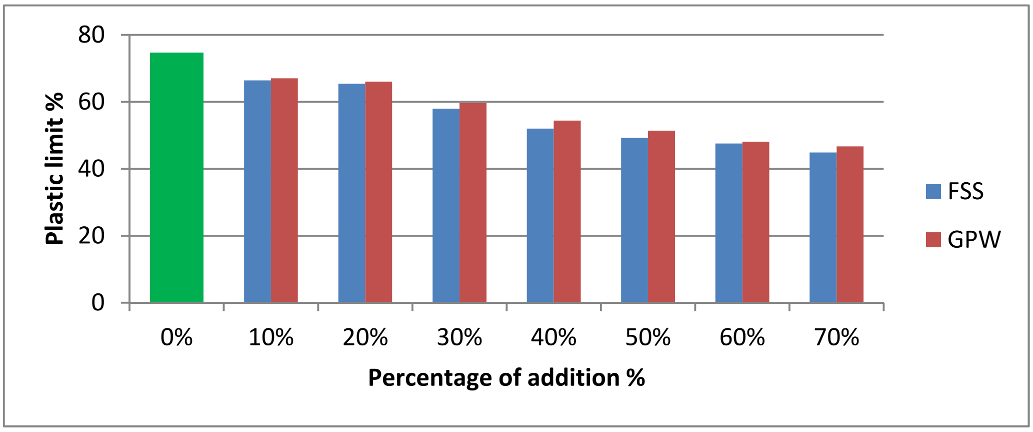

Figure 4. Effects of Fine Silica Sand versus Effects of Granite Waste Powder on the Plastic Limit

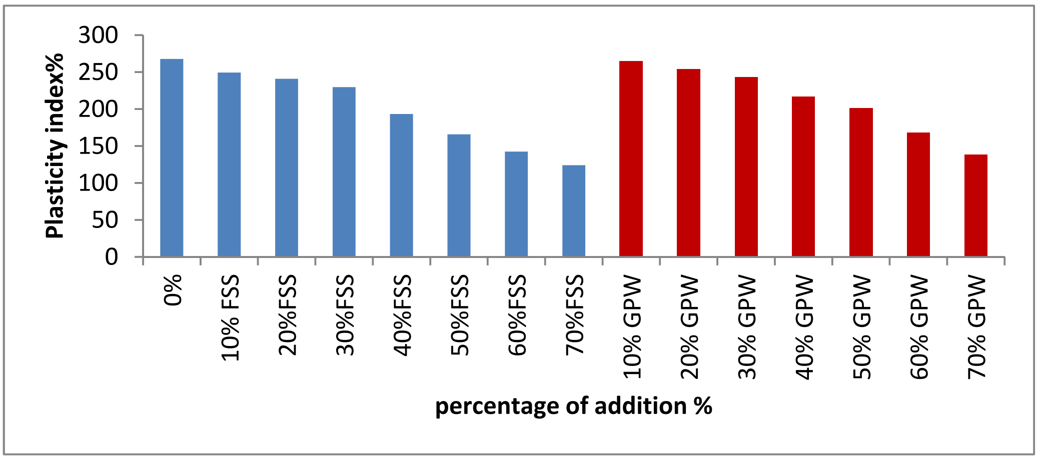

Figure 5. Effects of Fine Silica Sand and Granite Waste Powder Addition on the Plasticity Index

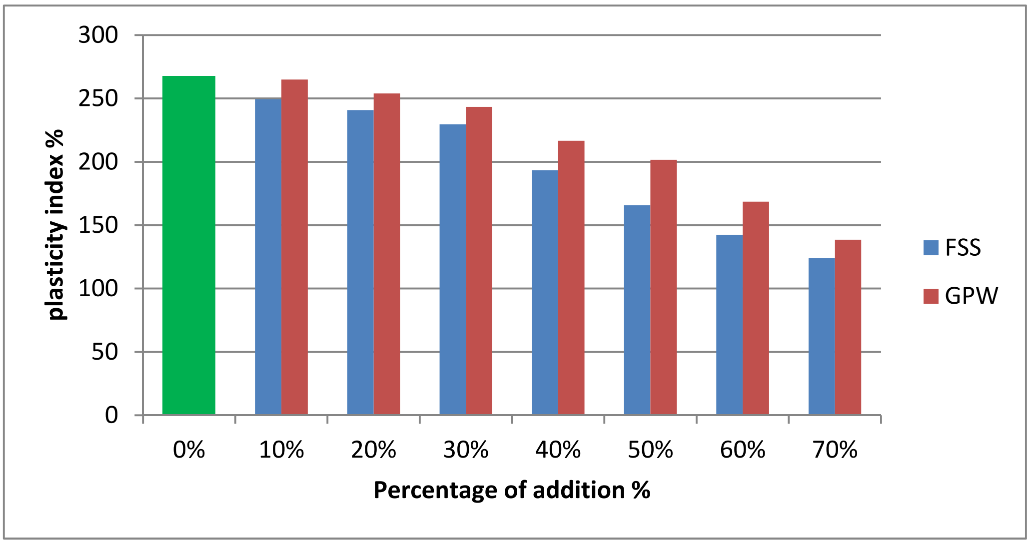

Figure 6. Effects of Fine Silica Sand versus Effects of Granite Waste Powder on the Plasticity Index

Figure1to Figure 3 shows the relationship between (LL, PL, and PI) and the percentage of fine silica sand and granite powder waste. The relationship between PI and percentage of mixed fine silica sand and the relationship between PI and granite powder waste is also approximately linear. Addition of 70% fine silica sand reduced the expansive soil plasticity to about 54% of the initial value. While addition of 70% granite powder waste reduced the expansive soil plasticity to about 48%.

Addition of fine silica sand from (0% to 70%) decreased the plasticity index value from 267.83% to 124.12%, while addition of granite powder waste from (0% to 70%) decreased the plasticity index value from 267.83% to 138.51% as show in table 3.

B. Effect of Fine Silica Sand and Granite Powder Waste Addition on Expansive Soils Free Swelling Properties

Free swell index is the increase in volume of a soil, without any external constraints, on submergence in water. The free swell index may be considered as a property of expansive soil. It reflects the potential of the soil for its expansion. It is determined by finding out the volume of the swollen soil after allowing a specified volume of the dry soil to get soaked in water. The free swell index is expressed as percentage free swell given by the equation below:

$$\text{Free Swell} = \frac{\text{Final Volume} - \text{Initial Volume}}{\text{Initial Volume}} \times 100 \ldots\ldots\ldots\ldots..1$$

Ranjan, G., and Rao, A. S. R. [11] gave the following classification of degree of expansion based on the Free swell index values (Table 4).

Table 4. Degree of expansion and differential free swell index (Ranjan, G., and Rao, A. S. R.) [11]

Free Swell Index %	Degree of Expansion
Less Than 20	Low
20 to35	Moderate
35 to50	High
Greater than 50	Very High

Table 5 and Figure 7 to Figure 10 show the effect of each fine silica sand and granite powder waste stabilizers on free swell index. The free swell decreases with increases of fine silica sand and granite powder waste additives.

Adding 70% fine silica sand reduced the swell index to 5.66% from 31.6% on the first day, and adding 70% granite powder waste reduced the swelling potential to 6.5% on the first day.

To explain the effect of fine silica sand and granite powder waste on the swelling potential we can look at the results of 70% granite powder waste and 70% fine silica sand after 7 days. 70% fine silica sand showed a swelling index percentage of 6.6% and 70% granite powder waste showed a swelling index percentage of 11%. This shows that fine silica sand is more table4 show that addition of the silica sand and granite powder waste change the swelling potential of expansive soils sample which classified as a high swelling potentially soil to low expansive soils.

Table 5. Proposed Expansive Soils Free Swell index and Degree of Expansion

Percentage of Fine Silica Sand Addition	**Free Swell Index (%)**			**Degree of Expansion According To (Ranjan, G., and Rao, A. S. R.) [7]**	**Percentage of Granite Powder Waste Addition**	**Free Swell Index (%)**			**Degree of Expansion According To (Ranjan, G., and Rao, A. S. R.) [7]**
	1 days curing	2 days curing	7 days curing			1 days curing	2 days curing	7 days curing	
0	31.6	43.3	58.3	Very High	0	31.6	43.3	58.3	Very High
10	28.2	36.3	50	High	10	30.33	36.66	56.3	Very High
20	25.4	33.2	41.6	High	20	28.1	34.4	46.66	High
30	23.8	29.5	36.8	Moderate	30	26.6	30.1	42.33	Moderate
40	19.5	27.6	31.6	Moderate	40	21	26.5	40	Moderate
50	13.3	21.6	26.5	Moderate	50	15.5	23.6	37.66	Moderate
60	9	11	16.6	Low	60	10.3	14	23.3	Low
70	5.66	6.0	6.6	Low	70	6.5	8.33	11	Low

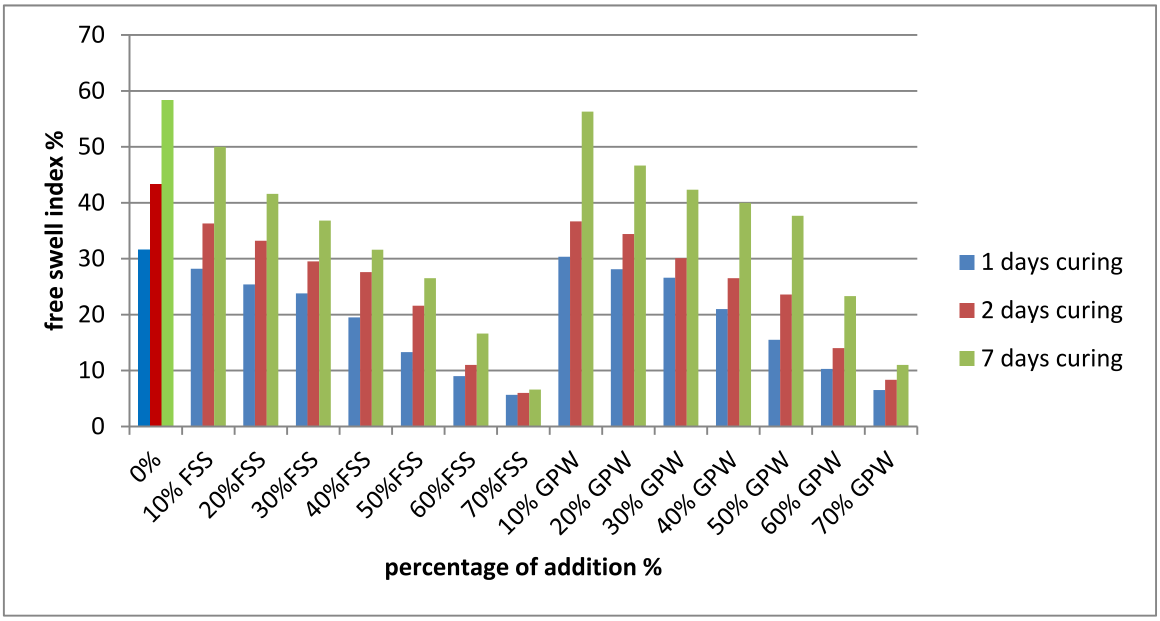

Figure 7. Effects of Fine Silica Sand and Granite Waste Powder on Free Swell Index at Different Curing Age

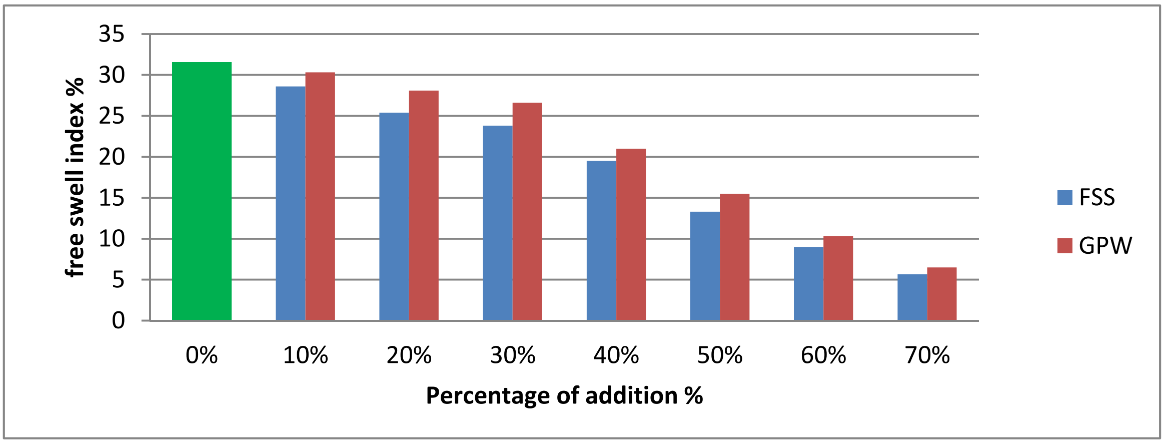

Figure 8. Effects of Fine Silica Sand versus Effects of Granite Waste Powder on Free Swell Index at 1days

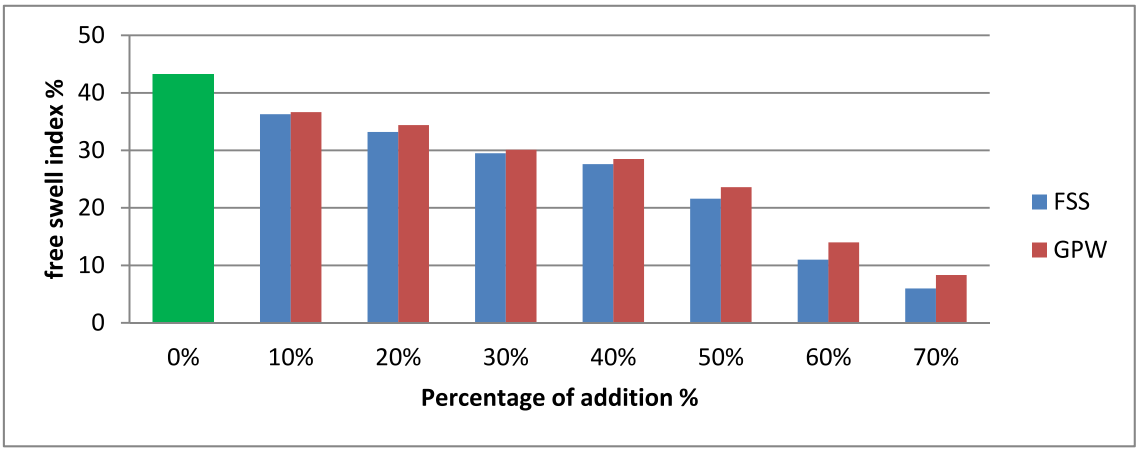

Figure 9. Effects of Fine Silica Sand versus Effects of Granite Waste Powder on Free Swell Index at 2days

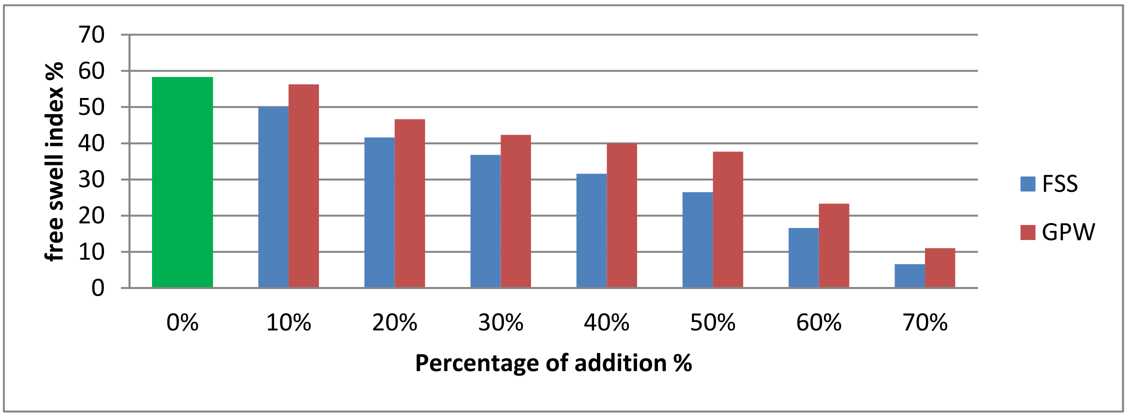

Figure 10. Effects of Fine Silica Sand versus Effects of Granite Waste Powder on Free Swell Index at 7days

4. Effects of Fine Silica Sand and Granite Powder Waste Addition on Rate of Swell of the Expansive Soil

Adding fine silica sand and granite powder waste definitely affects the rate of swell. In comparison between fine silica sand and granite powder waste, fine silica sand is very effective in reducing the rate of swell with time. Especially when 70% fine silica sand is added to the expansive soil it is conceivable to visualize the decrease in rate of swell as show in table 5 and figure 7 to figure 10.

5. Comparison of Test Results and Conclusion

In this study, the suitability of fine silica sand and granite powder waste as stabilizers for swelling potential of an expansive soil was investigated. The effect of fine silica sand and granite powder waste on the index properties and swelling behaviour of expansive soils by means of various laboratory tests such Atterberg limits (liquid limit, plastic limit and plasticity index) and free swelling index test. Fine silica sand and granite powder waste were used as additive materials with 10%, 20%, 30%, 40%, 50%, 60 & 70% by dry weight of the expansive soils.

Based on the analysis of laboratory results obtained and comparisons made in the present study, the following conclusions were drawn:

- Liquid limit, plastic limit and plasticity index values of expansive soil decreased with the addition of silica sand and granite powder waste
- Addition of the fine silica sand and granite powder waste change the swelling potential of expansive soils sample which classified as a high swelling potentially soil to low expansive soils.
- Addition of fine silica sand and granite powder waste to the expansive soils sample reduces swell index percentage significantly addition of 70 % fine silica sand change swell index percentages from 58.3% to 6.6% after 7 days of curing with reduction percentage of 88.7%, while addition of 70% granite powder waste change swell index percentages from 58.3% to 11% after 7 days of curing with reduction percentage of 81.1%.
- Swelling percentage and rate of swell decrease by increase of curing time for both fine silica sand and granite powder waste soils samples.
- It should be noted that the current laboratory investigation focuses mainly on bentonite materials as soils sample with high expansive potential so it is suggested to use natural expansive soils samples with different degree of swell potential which proves the influence of fine silica sand and granite powder waste on swelling behaviour more exactly.
- On the basis of this study both fine silica sand and granite powder waste can be used as effective additives materials for improvement of expansive soils for the construction of different structures. The utilized of fine silica sand and granite powder waste as additive materials can be economically in regions near to the areas where these materials are obtained.

The results obtained in this study, fine silica sand and granite powder waste have significant change the expansive soils index properties. Therefore, fine silica sand and granite powder waste can be used as stabilizer materials for highly plastic expansive soils. Although the two materials give different results, however, the results obtained using granite powder waste as soil stabilizer were close to fine silica sand results as shown in figure 2, figure 4, figure 6, figure 8, figure 10, and table 6 which makes granite powder waste and natural stone powder waste as general can effectively improve the poor properties of expansive soil more over these materials are cost effectively, locally available and environmentally friendly.

Table 6. Percent Changes in Free swell index and Rate of Swell

Percentage of Fine Silica Sand Addition	**% Change in Free Swell Index (%)**			**Percentage of Granite Powder Waste Addition**	**% Change in Free Swell Index (%)**		
	1 days curing	2 days curing	7 days curing		1 days curing	2 days curing	7 days curing
0	0	0	0	0	0	0	0
10	-10.8	16.16-	-14.2	10	4.0-	15.33-	3.4-
20	19.6-	23.3-	28.6-	20	11.1-	20.6-	19.9-
30	-24.7	31.9-	36.9-	30	15.8-	30.5-	27.4-
40	38.3-	36.3-	45.8-	40	33.5-	38.8-	31.4-
50	-57.9	50.1-	54.5-	50	50.9-	45.5-	35.4-
60	71.5-	74.6-	71.5-	60	67.4-	67.7-	60.0-
70	82.1-	86.0-	88.7-	70	79.4-	80.8-	81.1-

*(-) Shows the decrease in values

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References

Ene, E., & Okagbue, C. (2009). Some basic geotechnical properties of expansive soil modified using pyroclastic dust. *Engineering Geology, 107*(1-2), 61-65. https://doi.org/10.1016/j.enggeo.2009.03.007

Gupta Chayan, & Sharma Ravi Kumar. (2014). Influence of Marble Dust, Fly Ash and Beas Sand on Sub-Grade Characteristics of Expansive Soil. *Journal of Mechanical & Civil Engineering*, 13-18.

Jain, A., Gupta, R., & Chaudhary, S. (2019). Performance of self-compacting concrete comprising granite cutting waste as fine aggregate. *Construction and Building Materials, 221*, 539-552. https://doi.org/10.1016/j.conbuildmat.2019.06.104

Mishra, B., & Mishra, R. S. (2015). Improvement in Characteristics of Expansive Soil by Using Quarry Waste and Its Comparison with Other Materials like Cement and Lime Being Used for Soil Improvement. *International Journal of Innovative Research in Science, Engineering and Technology, 4*, 7416-7431.

Monica Malhotra, & Sanjeev Naval. (2013). Stabilization of Expansive Soils Using Low Cost materials. *International Journal of Engineering and Innovative Technology, 2*(11).

Muntohar, A. S., & Hantoro, G. (2000). Influence of Rice Husk Ash and Lime on Engineering Properties of a Clayey Subgrade. *Electronic Journal of Geotechnical Engineering, 5*, 1-13.

O'neıll, M. W., & Poormoayed, N. (1980). Methodology for Foundations on Expansive Clays. *Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, 106*(GT12), 1345-1367.

Öncü, Ş., & Bilsel, H. (2018). Utilization of waste marble to enhance volume change and strength characteristics of sand-stabilized expansive soil. *Environmental Earth Sciences, 77*(12). https://doi.org/10.1007/s12665-018-7638-5

Oriola, F. O. P., & Moses, G. (2011). Compacted Black Cotton Soil Treated with Cement Kiln Dust as Hydraulic Barrier Material. *American Journal of Scientific and Industrial Research, 2*, 521-530. https://doi.org/10.5251/ajsir.2011.2.4.521.530

Ramakrishna, A. N., & Pradeep Kumar, A. V. (2006). Stabilisation of Black Cotton Soil Using Rice Husk Ash and Cement. *National Conference on Civil Engineering Meeting the Challenges of Tomorrow*, GND Engineering College, Ludhiana, 215-220.

Ranjan G., & Rao, A. S. R. (2000). *Basic and Applied Soil Mechanics*. New Age International Publishers. Second Edition.

Selvakumar, S., & Soundara, B. (2020). Swelling behavior of expansive soils stabilized with expanded polystyrene geofoam inclusion. *New Materials in Civil Engineering,* 745-776. https://doi.org/10.1016/B978-0-12-818961-0.00024-7

Sumit S., Vishvendra S., & B. Achary. (2018). Review on effect of marble dust on geotechnical properties of expansive soil. *International Journal of Advance Research in Science and Engineering (IJARSE), 7*(2).

Talal Masoud, Manal O. Suliman, Shehdeh Ghannam, & Hesham Alsharie. (2019). Effect of Alkhmhah on Swelling Index Properties of Expansive Soils From Jerash in Jordan. *International Review of Basic and Applied Sciences, 7*(12), 93-98.

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