Mühendislik Bilimleri ve Tasarım Dergisi
7(3), 522 – 538, 2019
e-ISSN: 1308-6693

Journal of Engineering Sciences and Design
DOI: 10.21923/jesd.520126

Araştırma Makalesi Research Article

A COMPARISON OF QUARTZ SANDS WITH DIFFERENT MINERALOGY AND THEIR GRIDING DERIVATIONS

Seda ÇELLEK[*]

Kırşehir Ahi Evran University, Faculty of Engineering, Dept. of Geology Engineering, Kırşehir, Turkey

Keywords

Quartz sand,
Griding,
Void ratio,
Angle of internal friction,
Cohesion.

Abstract

Griding sand is specifically used to treat clays that tend to swell. Each of the sands has its unique physical properties. For that reason, it is necessary to determine the engineering properties of the sand used. In this study, four types of sand with different mineralogy were examined. After determining the engineering properties of these sands, three different specimens per sample, with different size distributions, were obtained by grinding them up to the size of clay and silt. As a result, it was determined that the twelve sand samples consisted of poorly sorted sand and the physical properties of the sands with different mineralogy were different to each other. The largest difference in derivatives was found in Type 1 sand of magmatic origin. It was observed that the original sand used in all experimental results gave higher values than the finer grained derivative samples. As a result, the engineering properties of the sands changed with the reduction in grain sizes. In addition, it was determined that the derivatives obtained by grinding the sand with different mineralogy exhibit different behaviors.

FARKLI MİNERALOJİYE SAHİP KUVARS KUMLARI VE ÖĞÜTÜLMÜŞ TÜREVLERİNİN KARŞILAŞTIRILMASI

Keywords

Kuvars kumu,
Öğütme,
Boşluk oranı,
İçsel sürtünme açısı,
Kohezyon.

Öz

Öğütülmüş kumlar, özellikle şişme eğiliminde olan killerin iyileştirilmesinde kullanılmaktadır. Her kum kendine özgü fiziksel özelliklere sahiptir. Bu nedenle kullanılan kumun mühendislik özelliklerinin belirlenmesi gerekmektedir. Bu çalışmada farklı mineralojiye sahip 4 kum kullanılmıştır. Bu kumların mühendislik özellikleri belirlendikten sonra, kil ve silt boyutuna kadar öğütülerek her numuneden farklı tane dağılımlarına sahip, 3'er numune elde edilmiştir. 12 kumun "Kötü derecelenmiş kum" olduğu, farklı mineralojiye sahip kumların fiziksel özelliklerinin de farklı olduğu belirlenmiştir. Türevler içinde en büyük farklılık magmatik kökene sahip Tip 1 kumunda görülmüştür. Sonuç olarak, kumların, tane boyutlarının küçülmesiyle mühendislik özellikleri değişmiştir. Ayrıca farklı mineralojiye sahip kumların öğütülmeleriyle elde edilen türevlerin farklı davranışlar sergiledikleri belirlenmiştir.

Alıntı / Cite

Çellek, S., (2019). A Comparison of Quartz Sands with Different Mineralogy and Their Griding Derivations, Journal of Engineering Sciences and Design, 7(3), 522-538.

Yazar Kimliği / Author ID (ORCID Number)	Makale Süreci / Article Process	
S. Çellek, 0000-0001-9675-5691	**Başvuru Tarihi / Submission Date**	31.01.2019
	Revizyon Tarihi / Revision Date	05.03.2019
	Kabul Tarihi / Accepted Date	02.04.2019
	Yayım Tarihi / Published Date	15.09.2019

1. Introduction

Fine grained soils create many problems in engineering structures due to volume changes caused by swelling processes (Yılmaz and Çelik, 2012). In order to control these kinds of volume changes, swelling soils are stabilized with additives. The consolidation and swelling behavior of clay can be

---

[*] İlgili yazar / Correspondingauthor: sedacellek@ahievran.edu.tr, +90-386-280-3820

countered by griding quartz sand. As a result of consolidation and swelling tests, the ratio of griding sand increased as the swelling pressure and volumetric compressive coefficient (mv) decreased, and the consolidation coefficient increased. This means that any settlement will decrease. The consolidation coefficients obtained from the samples with 50% by weight of sand were 4 times higher than the consolidation coefficients obtained from the samples with no sand added. This means that the addition of 50% sand to the clayey soil can help to reduce the rate of settlement by a factor of four (Yılmaz, 2012; Yılmaz and Çelik, 2012; Batmaz, 2015).

In clayey sand, by reducing the clay ratio with an increase in the sand ratio, maximum porosity is reached by filling the voids. Due to the changes in the structure, the compressibility and behavior of the clay material is transformed from clay-like characteristics to sand-like characteristics (Wasti and Alyanak, 1968; Batmaz, 2015).

In this study, the results of different grinding sands were investigated. The experimental results showed that the experimental results of the grinded sand of the same sand were very different. This hasn't been valid for every sand. Mineralogy also has great influence on griding sands

2. Scientific Literature Review

The grains that make up the soil are not equal in size. The small grains that fill the gaps between the large grains produce higher density and lower voids than a structure where the spherical grains are all the same size. The materials on the soil may range from the smallest grains, such as clay, to the largest size material, such as gravel. Each classification of different size particles has a different role within the griding. In published literature, there are studies that investigate the mechanical behavior (shear strength, internal friction angle etc.) of materials by adding sand to materials such as clay and silt (Wasti and Alyanak, 1968; Bayoğlu, 1995; Vallejo and Mawby, 2000; Karabüyük, 2001; Zorluer et al., 2003; Kumar et al., 2006; Ünverdi, 2006; Çanakçı and Güllü, 2007; Güven, 2007; Durmuş, 2007; Alagöz, 2008; Dağdeviren et al., 2008; İkizler et al., 2008; Ölmez et al., 2008; Başer et al., 2010; Çimen et al., 2010; Yılmaz, 2012 and Çelik, 2015). While the ratio of clay and silt increases, the plastic properties are not expected to change, and the amount of sand in the sample will not affect the mineralogical properties of the clay. Clay particles are much more prone to stick together compared to sand. Besides, the silt tends to be spherical (round). Therefore, it is more difficult to shape than clay, and because of its spherical shape, silt can hold large amounts of water. The ability of very fine sand grains to adhere to other is very small. The sand samples used in the study were griding down to obtain samples of different grain sizes. The void ratios of the samples were determined through specific gravity experiments. For the sand samples, different bending values, shear box and oedometer tests were carried out with different load values. Internal friction angles (ϕ) and shear strengths (σ) were determined by shear box experiments, and values such as the elasticity coefficient and the void ratio were determined by consolidation tests.

3. Materials and Methods

Ten kilograms of sand was taken from the locations chosen as the study area. In the study, the sand samples used were taken from the coastal areas of Trabzon (Type 1), Sinop (Type 5), Zonguldak (Type 9), and from the Menderes River (Basin) of Çine (Aydın) (Type 13) (Figure 1). A river bed in the Aegean region was selected as sampling locations for the sand samples, with three locations in the eastern, middle and western portion of the Black Sea region shoreline.

Figure 1. Locations of the samples taken for the study

In the sample locations selected, the region's geology and their basin formations were considered. Trabzon sand was taken from a volcano-sedimentary series, Sinop and Zonguldak sands were sampled from a sedimentary basin, and Çine sand was taken from a metamorphic area. The four sand samples used in the study were griding down to the sizes of clay, silt and fine sand and new samples produced from these materials. Type 1 sand was taken from Trabzon, and after a milling process, its derivatives were called grinding Types 2, 3 and 4. Type 5, which was obtained by grinding the sand taken from Sinop, produced derivatives called Types 6, 7 and 8. Derivatives of Type 9, which was taken from Zonguldak, were classified as Types 10, 11 and 12. Finally, derivatives obtained from Type 13 from Çine were called Types 14, 15 and 16.

4. Findings

Each sand sample was griding down to produce 3 different samples of specific grain sizes. Hydrometer according to standards ASTM D 422 (1998) and specific gravity according to standards ASTM D854 – 14 (2014) tests were performed on the samples produced and their properties were determined.

Also, Maximum Index Density (ASTM D 4253–00, 2006) and Minimum Index Density (ASTM D 4254–00, 2006) determined by standards. The minimum void ratios (emin) and maximum void ratios (emax) were calculated by using empirical formulas with minimum and maximum dry unit volume weight.

The materials were classified on sieve #100, under sieve #100, on sieve #200, under sieve #200, and on sieve #325. In total, 12 samples were obtained from 3 different groups of 4 types of sand. More than half of the samples to be used in the study were called 'fine-grained griding' because they passed through sieve #200. Due to the dry conditions during the sieving, the grain distribution of 3 samples was determined by hydrometer experiments. The study was based on the density values of the original sand. Samples for the shear box (ASTM D3080), prepared from the series of 4 sands of the same weight, were tested with a constant velocity of 0.5 mm/second with tensile values of 50, 100, 200 and 400 kPa. Consolidation experiments according to standards ASTM D 2435-03 (2003) were also carried out with equal weights determined by the same method.

In order to reduce the size of the sand used in the study – in comparison to the silt and clay – grinding was carried out for 1 hour. The grinding process continued in a ball mill until grain sizes ranged from 15 mm to 20 microns (powder). The process was carried out by crushing the samples between 20 mm diameter iron balls in a rotating cylinder (Figure 2).

Figure 2. Grinding the sand samples

4.1. Comparison of The Physical Properties of Griding Sand and Original Sand

The mineralogical contents of the sands have been determined by XRD studies is given at Table 1.

The dry density and void ratios of the sand samples used in the study were determined by experiments. The specific gravity (Gs) of the sands used in the experiments varied from 2.74 to 3.44.

Table 1. Mineralogical contents of the sands

TYPE	WEIGHT (%)	NAME OF THE MINERAL	MINERAL FORMULA
1	53	Augite	$Ca(Mg,Fe)Si_2O_6$
	20	Diopside	$Ca(Mg,Al)(Si,Al)_2O_6$
	20	Hedenbergite	$CaFe^{+2} Si_2O_6$
	7	Fayalite	$Fe^{+2} SiO_4$
5	57	Quartz	SiO_2
	43	Anorthite	$CaAl_2Si_2O_8$
9	80	Quartz	SiO_2
	20	Anorthite	$CaAl_2Si_2O_8$
13	48	Quartz	SiO_2
	31	Anorthite	$CaAl_2Si_2O_8$
	20	Muscovite	$KAl_2Si_3AlO_{10}(OH)_2$

The content of the Type 1 sand that has a high specific gravity – determined by X-ray diffractometer (XRD) studies –consists of iron, mica and muscovite. The other three sand samples displayed standard quartz sand properties and were made up of quartz and mica minerals in general. Specific gravity values depend on mineral types and grain sizes. In Figures 3, 4, 5 and 6, the grain distribution of sand samples and their derivatives is given, while the distribution amounts are given at Tables 2, 3, 4 and 5. Sieve analysis made according to standard ASTM D-422 (1998).

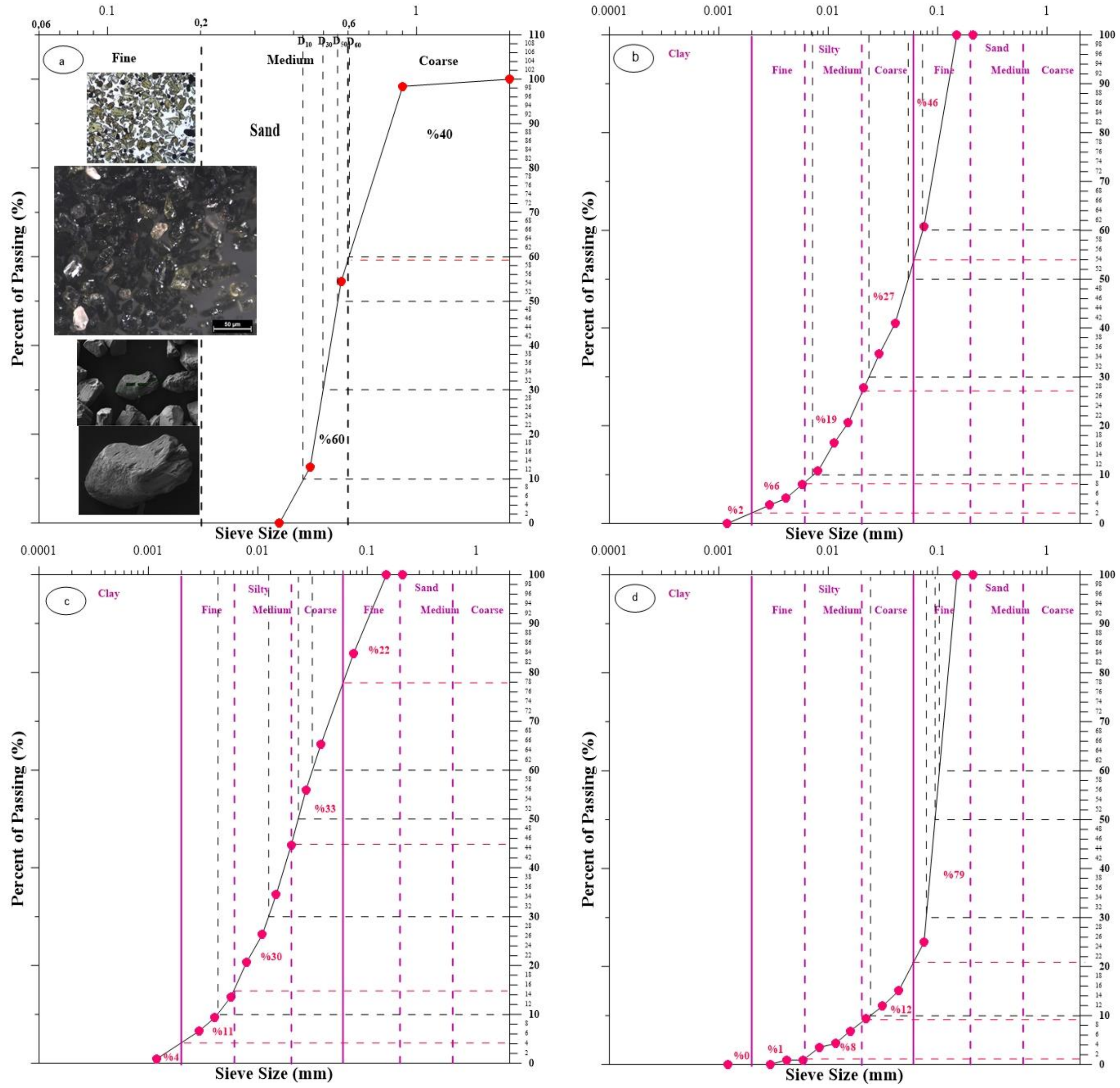

Figure 3. Comparison of Type 1, 2, 3 and 4 (Trabzon) granulometric curves for: a) original sand and (b, c, d) different degrees of griding derivatives.

Table 2. Calculations for sand Types 1, 2, 3 and 4 (Trabzon)

TRABZON	TYPE 1	TYPE 2	TYPE 3	TYPE 4
COARSE SAND	40%	0%	0%	0%
MEDIUM SAND	60%	0%	0%	0%
FINE SAND	0%	46%	22%	79%
COARSE SILT	0%	27%	33%	12%
MEDIUM SILT	0%	19%	30%	8%
FINE SILT	0%	6%	11%	1%
CLAY	0%	2%	4%	0%

Type 1 sand, which has higher specific gravity than the other three sand types, was subjected to grinding for a long time relative to the other sands. As a result, three fine-grained samples were produced with the thickest size corresponding to a fine-grained sand size.

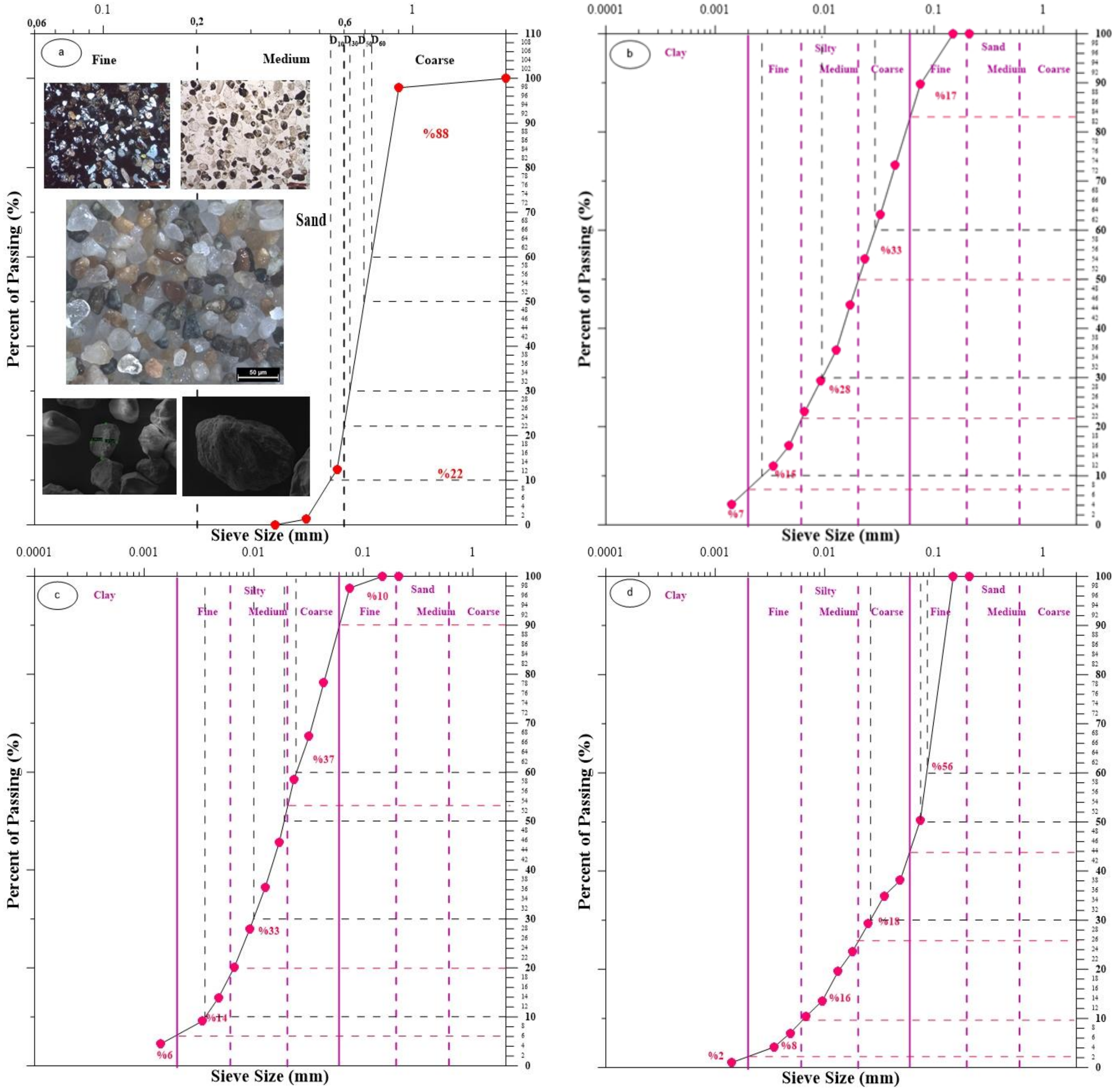

Figure 4. Comparison of granulometric curves for Types 5, 6, 7 and 8 (Sinop) a) original sand and (b, c, d) different degrees of griding derivatives.

Table 3. Calculations for Types 5, 6, 7 and 8 (Sinop)

SINOP	TYPE 5	TYPE 6	TYPE 7	TYPE 8
COARSE SAND	88%	0%	0%	0%
MIDDLE SAND	22%	0%	0%	0%
FINE SAND	0%	17%	10%	56%
COARSE SILT	0%	33%	37%	18%
MIDDLE SILT	0%	28%	33%	16%
FINE SILT	0%	15%	14%	8%
CLAY	0%	7%	6%	2%

Three different samples were obtained by the grinding process from Type 5 sand with a coarse grain size.

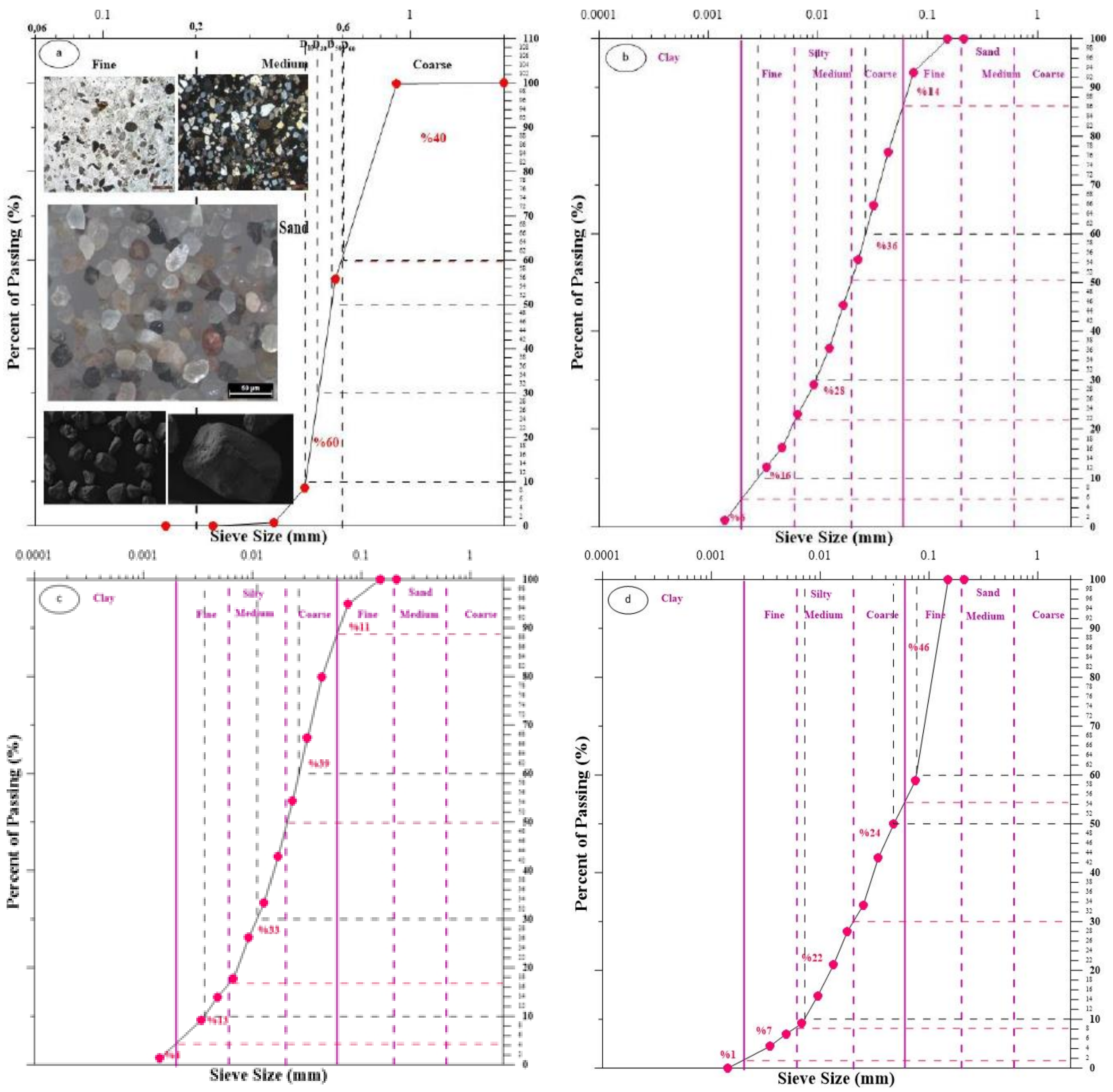

Figure 4. Comparison of the granulometric curves for Types 9, 10, 11 and 12 (Zonguldak). a) original sand and (b, c, d) different degrees of griding derivatives.

Table 4. Calculations for Types 9, 10, 11 and 12 (Zonguldak)

ZONGULDAK	TYPE 9	TYPE 10	TYPE 11	TYPE 12
COARSE SAND	40%	0%	0%	0%
MIDDLE SAND	60%	0%	0%	0%
FINE SAND	0%	14%	11%	46%
COARSE SILT	0%	36%	39%	24%
MIDDLE SILT	0%	28%	33%	22%
FINE SILT	0%	16%	13%	7%
CLAY	0%	6%	4%	1%

Type 9 sand which displays similar grain distribution such as Type 1 sand, however mineralogically it is much similar to Type 5 sand. Three different derivatives were prepared that display a different distribution relative to the other two sands. Three derivatives were also prepared by grinding of Type 13 sand.

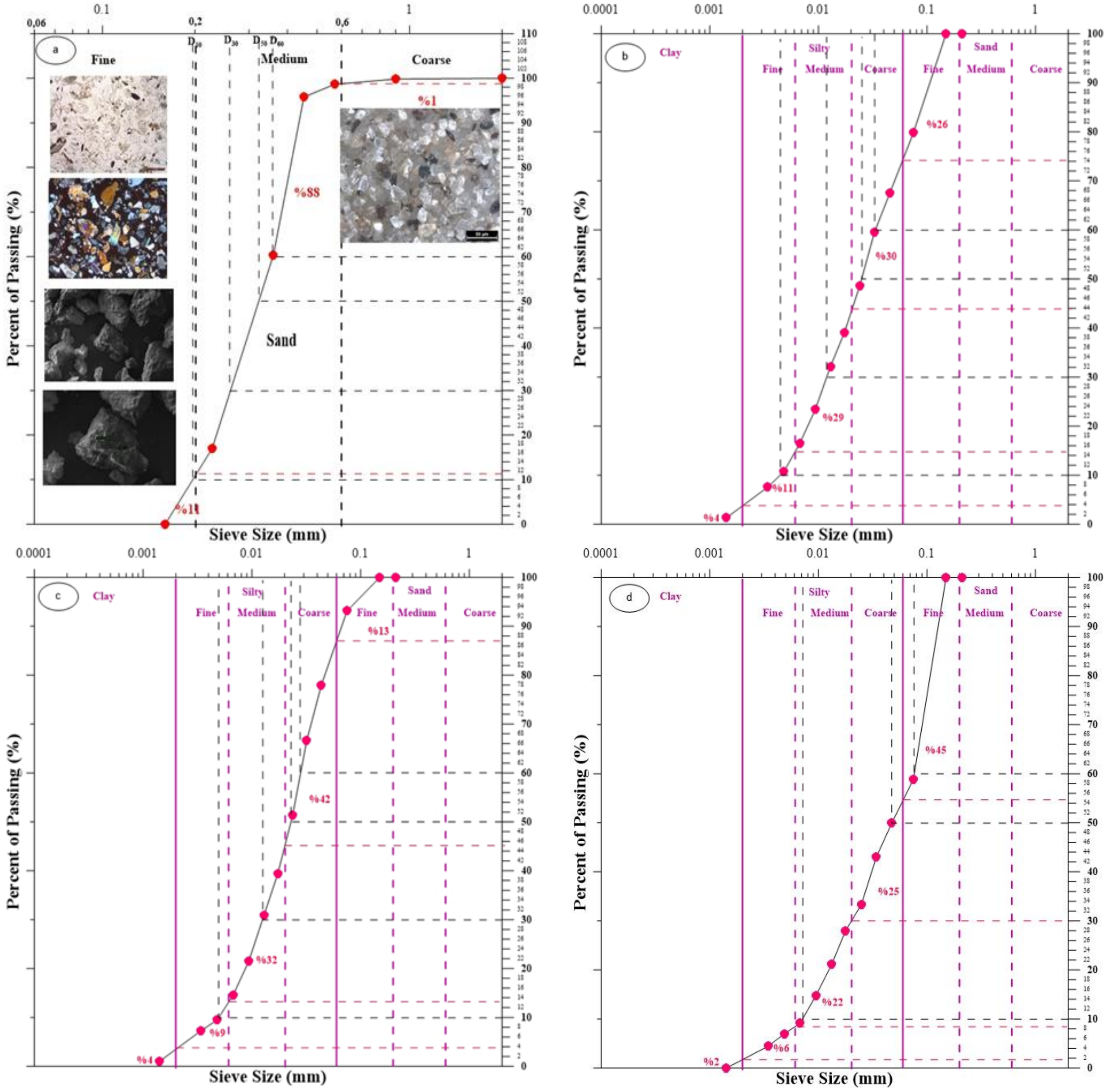

Figure 5. Comparison of granulometric curves for Types 13, 14, 15 and 16 (Çine). a) original sand and (b, c, d) different degrees of griding derivatives.

Table 5. Calculations for Types 13, 14, 15 and 16

ÇINE	**TYPE 13**	**TYPE 14**	**TYPE 15**	**TYPE 16**
COARSE SAND	1%	0%	0%	0%
MIDDLE SAND	88%	0%	0%	0%
FINE SAND	11%	26%	13%	45%
COARSE SILT	0%	30%	42%	25%
MIDDLE SILT	0%	29%	32%	22%
FINE SILT	0%	11%	9%	6%
CLAY	0%	4%	4%	2%

As a result of the grinding process, it is seen that the grains are below the original sand size. The pink field gives the original sand distribution, while the yellow area corresponds to the grain distribution of the grinded derivatives.

The sands are composed of thick, medium and very small amounts of fine grains, while the griding sand is generally composed of silt and a smaller amount of fine sand and clay. According to the ASTM D 2487-98 standard, the sands used in the study correspond to SP groups and their group name is collectively referred to poorly graded sand (Table 6).

Vertical particle size distribution curves reflect small particle size. These are known as poorly graded soils or uniformly graded soils. The condition of grading a sand-shaped soil is determined by graphically drawing the grain size distribution of that soil and calculating the curvature coefficient Cc with uniformity coefficient Cu on this curve. Particle diameters corresponding to specific percentages for a given soil are known as D dimensions. D60 is the grain diameter corresponding to 60% by weight or by mass. For example, D10 is the grain size corresponding to 10 percent. So 10 percent of the soil is thinner than D10. D10 is called the effective diameter and D50 is called the average diameter (Çellek, 2016; Kayabalı, 2010; Mollamahmutoğlu and Kayabalı, 2006; Aytekin, 2004). Two additional parameters, uniformity coefficient (Cu) and curvature coefficient (Cc) are based on dimensions D:

$$Cu = \frac{D_{60}}{D_{10}} \tag{1}$$

$$Cc = \frac{(D_{30})^2}{D_{10}D_{60}} \tag{2}$$

Cu: uniformity coefficient
Cc: curvature coefficient

Table 6. D$_{10}$, D$_{30}$, D$_{50}$, D$_{60}$, Cr and Cu values of the sands used in the study

Type	**D$_{10}$**	**D$_{30}$**	**D$_{50}$**	**D$_{60}$**	**Cr**	**Cu**
1	0.43	0.5	0.55	0.6	0.986	1.395
2	0.007	0.022	0.055	0.072	0.946	10.14
3	0.004	0.014	0.024	0.032	1.392	7.272
4	0.025	0.08	0.095	0.11	2.327	4.4
5	0.542	0.625	0.699	0.73	0.987	1.351
6	0.03	0.02	0.009	0.002	1.074	10.714
7	0.025	0.019	0.011	0.002	2	12.5
8	0.085	0.075	0.025	0.006	1.225	14.166
9	0.6	0.55	0.5	0.45	0.925	1.333
10	0.028	0.02	0.01	0.002	1.231	9.655
11	0.027	0.02	0.012	0.003	1.403	7.105
12	0.075	0.048	0.02	0.007	0.74	10.416
13	0.36	0.32	0.25	0.2	0.812	1.812
14	0.034	0.025	0.03	0.004	5.888	7.555
15	0.03	0.024	0.013	0.005	1.126	6.000
16	0.075	0.048	0.02	0.007	0.716	10.714

In all sands, as the grain size becomes smaller, Cr and Cu values increase. Each sand sample gave different D$_{10}$, D$_{30}$, D$_{50}$, D$_{60}$, Cr and Cu values.

When the results of sieve analysis were evaluated, it was determined that the coarsest material belonged to Type 5 sand, and the finest material belonged to Type 13 sand. In addition, the griding sands displayed different grain sizes ranging from clay size to fine sand.

The specific weights of Type 1, Type 5, Type 9 and Type 13 sands, the maximum and minimum dry weights (determined by experiment), and the maximum and minimum void ratios (calculated by empirical formulas) are shown in Table 7.

Specific Gravity (Gs) is the ratio of specific gravity of the solid to the specific gravity of water. It can obtained by measuring the weight of solid to the weight of water occupying equivalent volume of water. In other words, determination of porosity using a water pycnometer with capacitive level detection,

$$M_{water\ displaced\ by\ soil} = \rho_{water} x V_s \tag{3}$$

Where $\rho_{water} = density\ of\ water\ at\ temperature\ tested$

So, $M_{pws} = M_s + M_{pw} - \rho_{water} \times V_s$ (4)

Therefore, $V_s = \frac{M_s + M_{pw} - M_{pws}}{V_s}$ (5)

Combining with equation set

$$Gs\left(\frac{M_s}{M_s + M_{pw} - M_{pws}}\right)\left(\frac{\rho_{water}}{\rho_{water(20)}}\right) \tag{6}$$

Mpw: mass of the pycnometer full of water
Mpws: mass of the pycnometer full of water with soil
Ms: dry mas of soil

$$d_{max} = \frac{M_S}{V} \tag{7}$$

V: Volume of cap

$$e_{min} = \frac{G_S}{d_{max}} - 1 \tag{8}$$

e_{min}: Minimum void ratio
d_{max}: Maksimum dry density, gr/cm^3
e_{max}: Maksimum void ratio

$$d_{min} = \frac{M_S}{V} \tag{9}$$

$$e_{max} = \frac{G_S}{d_{min}} - 1 \tag{10}$$

e_{man}: Maksimum void ratio
d_{min}: Minimum dry density, gr/cm^3

Table 7. The specific gravity of the sands used in the experiments

Type	G_s	d_{max}	e_{min}	d_{min}	e_{max}
1	3.44	1.706	0.502	1.480	0.781
5	2.74	1.710	0.555	1.498	0.835
9	2.75	2.061	0.600	1.800	0.911
13	2.75	1.715	0.515	1.427	0.927

Type 1 sand displays specific gravity values (Gs) above standard sand values, while other sands produced normal values. The lowest e_{min} value belonged to Type 1, while the highest e_{max} value belonged to Type 13 sand.

4.2. Comparison of Oedometer Results Between Griding Sand and Original Sand

Oedometer experiments were performed for the samples used in the study. First of all, e–logσ graphs were produced. The results for the e–logσ graphs for Type 1, Type 5, Type 9 and Type 13 sands and their derivates are given in Figures 6-9.

When the e–logσ graphs are evaluated, it is seen that the griding sands give lower values than the original sands, and similar values to each other. Oedometer experiments were performed for samples prepared by compacting the griding sand by 40%, and the results were compared in Figure 10.

All four samples gave higher values than the griding samples. The largest difference is detected for Type 5 sand. The curves calculated for the griding sands display variations relative to the fine grain ratio. The elastic modulus–stress graphs were drawn for the sands, which were prepared with 40% tightness.

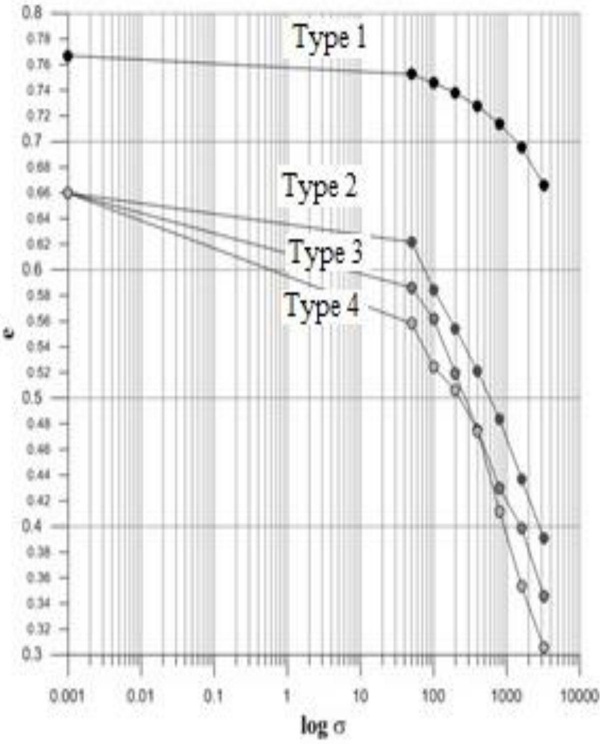

Figure 6.e–logσ graphics for the original sands compared to the griding derivative sands (Type1-4)

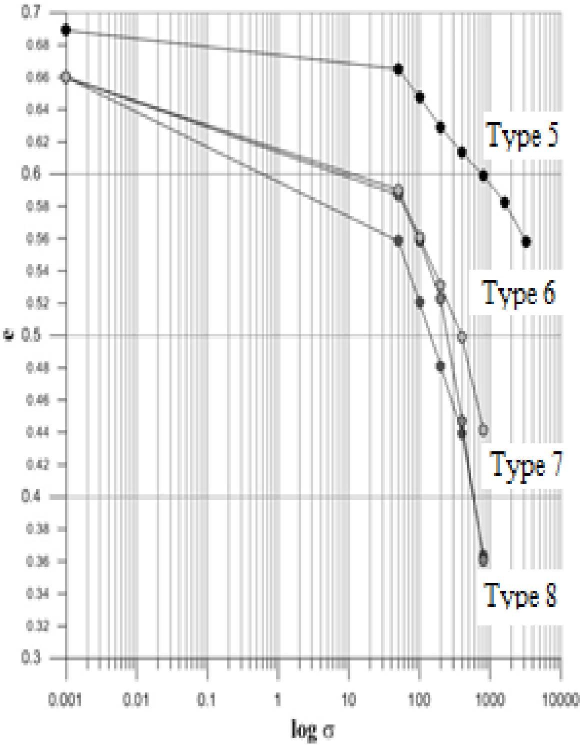

Figure 7. e–logσ graphics for the original sands compared to the griding derivative sands (Type 5-8)

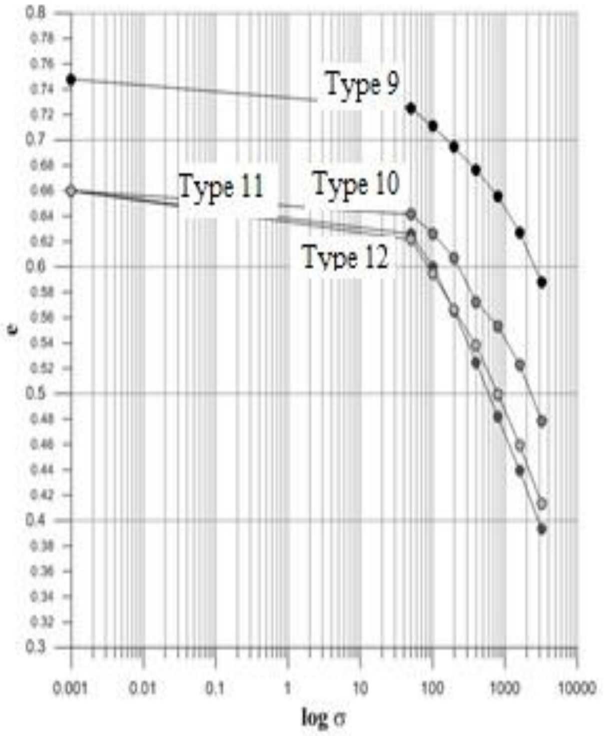

Figure 8. e–logσ graphics for the original sands compared to the griding derivative sands (Type 9-12)

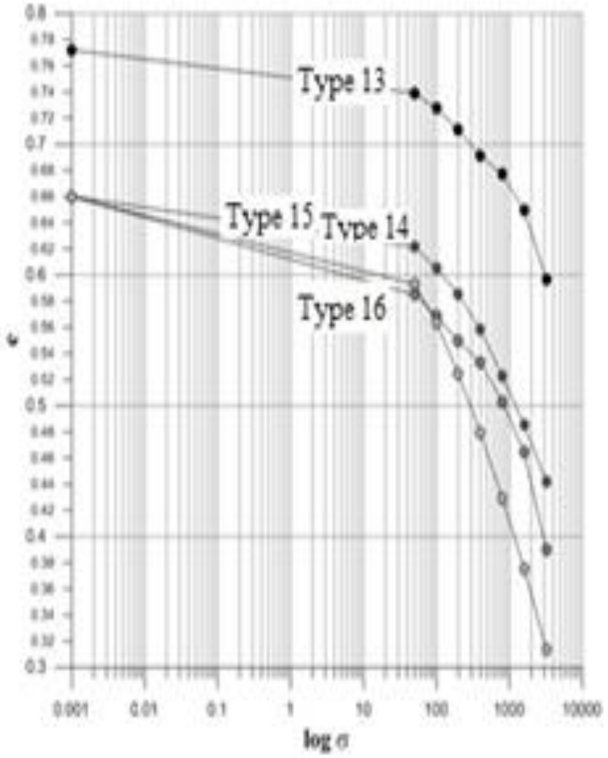

Figure 9. e–logσ graphics for the original sands compared to the griding derivative sands (Type13-16)

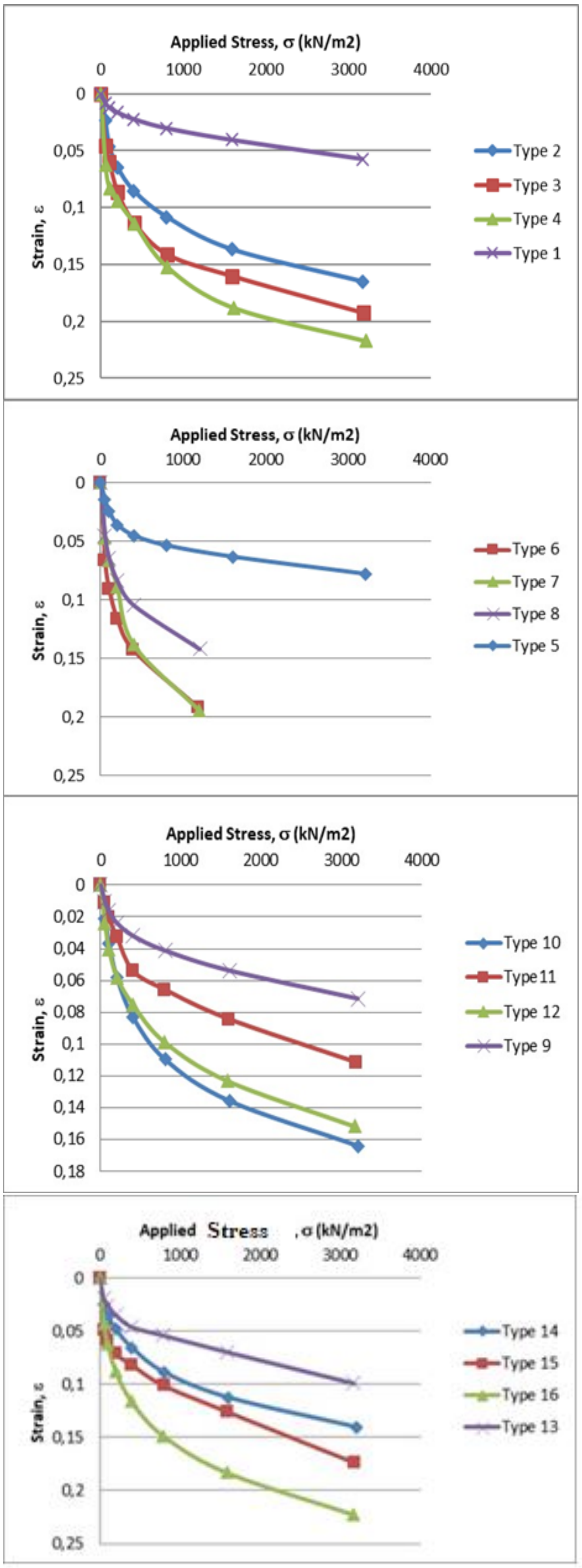

Figure 10. Comparative stress–strain deformation graphs of griding and original sands

The relative density of the field void ratio, e between maximum void ratio, emax and minimum void ratio, emin (Lade et al., 1998) can be defined as:

$$Dr = \frac{e_{max} - e}{e_{max} - e_{min}} x100 \quad (11)$$

Dr: Relative Density
e_{max}: void ratio of coarse grained soil (cohesionless) in its loosest state.
e_{min}: void ratio of coarse grained soil (cohesionless) in its densest state
e: void ratio of coarse grained soil (cohesionless) in its natural existing state in the field.

The results of the experiments are given in Figures 11-14.

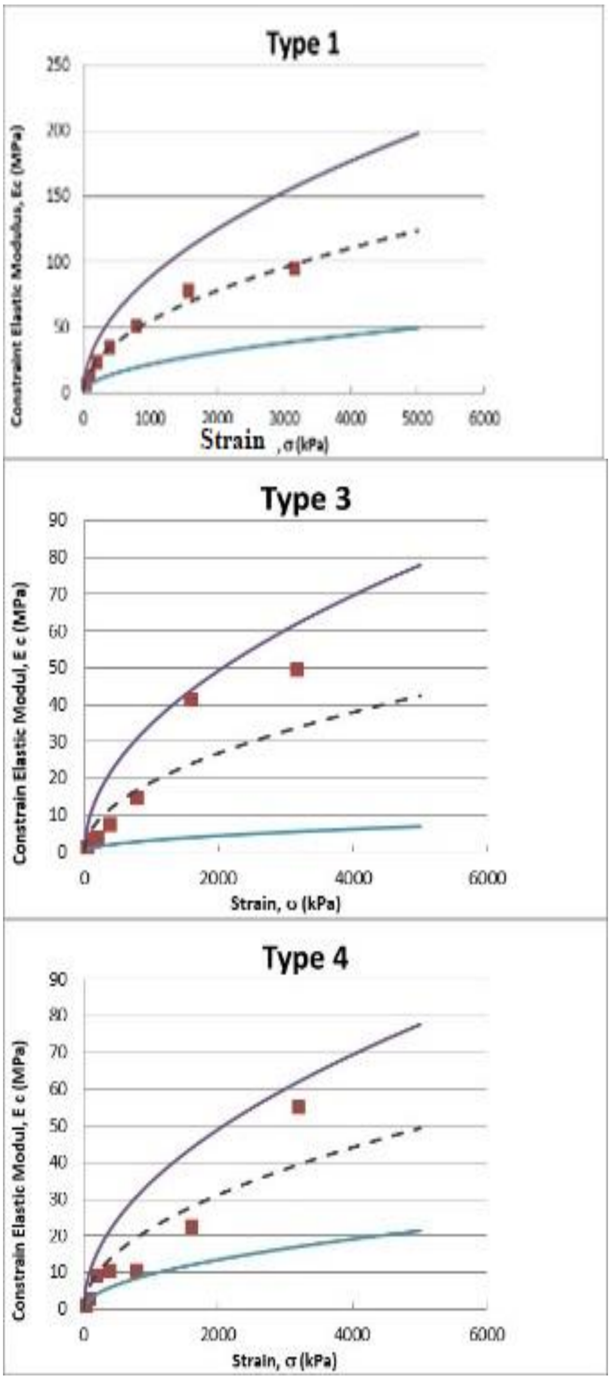

Figure 11. Constrained elastic modulus (Ec)–strain (σ) graphs for all sands (Type 1-4)

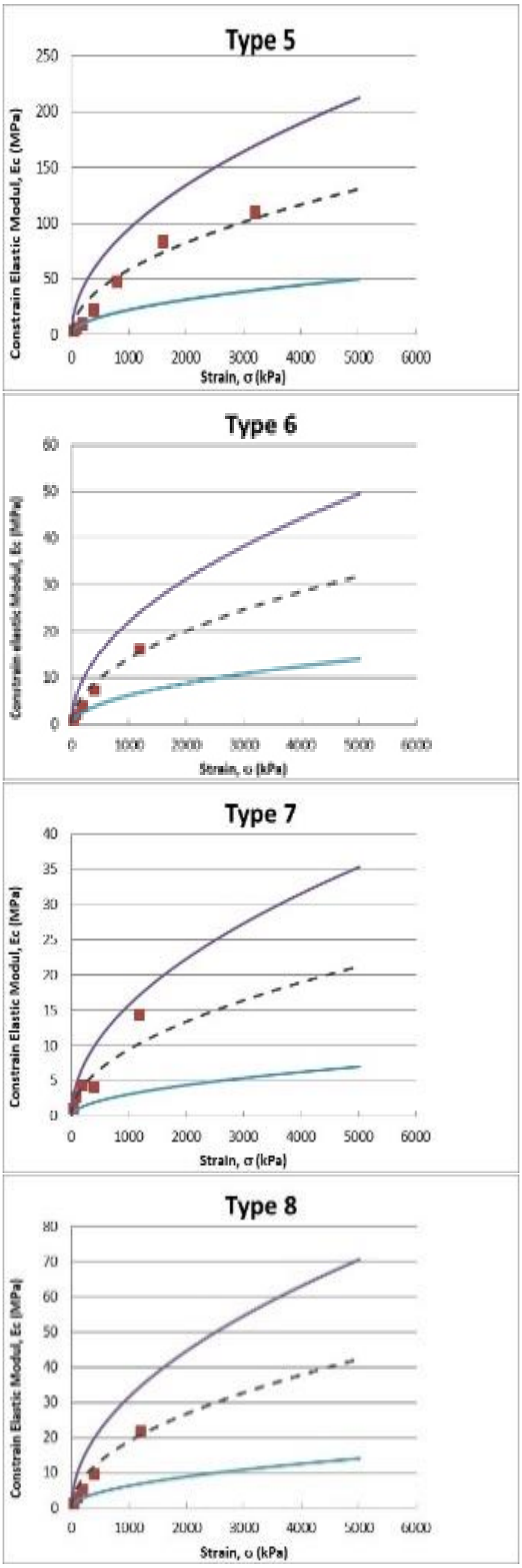

Figure 12. Constrained elastic modulus (Ec)–strain (σ) graphs for all sands (Type 5-8)

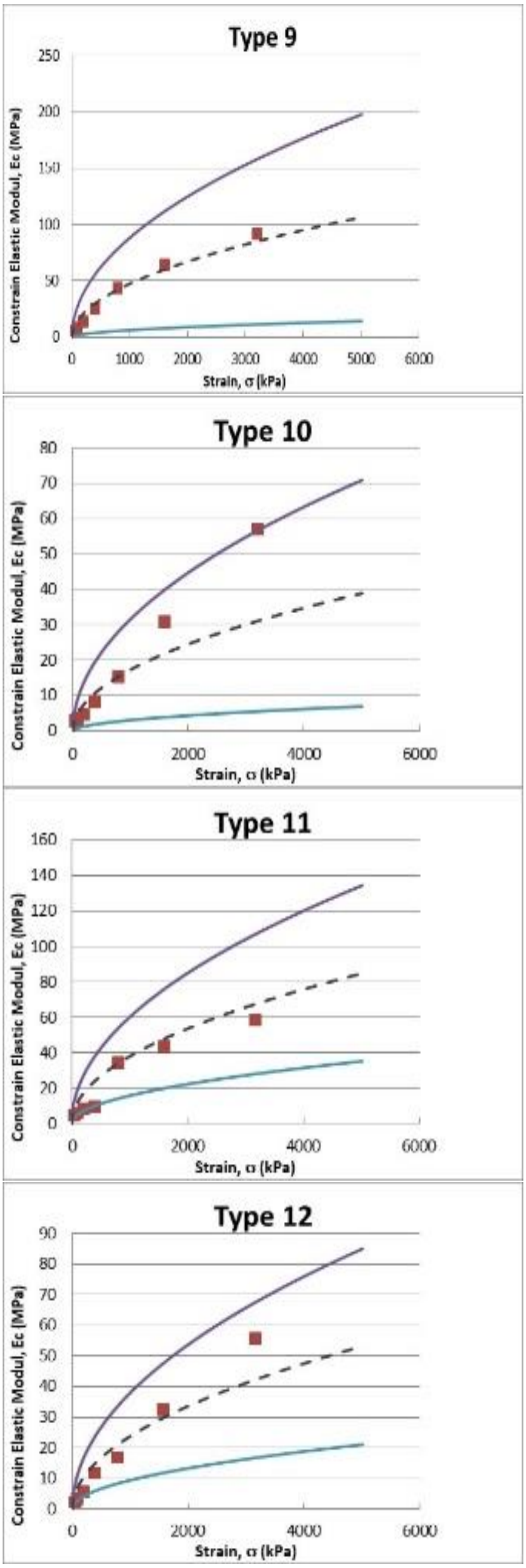

Figure 13. Constrained elastic modulus (Ec)–strain (σ) graphs for all sands (Type 9-12)

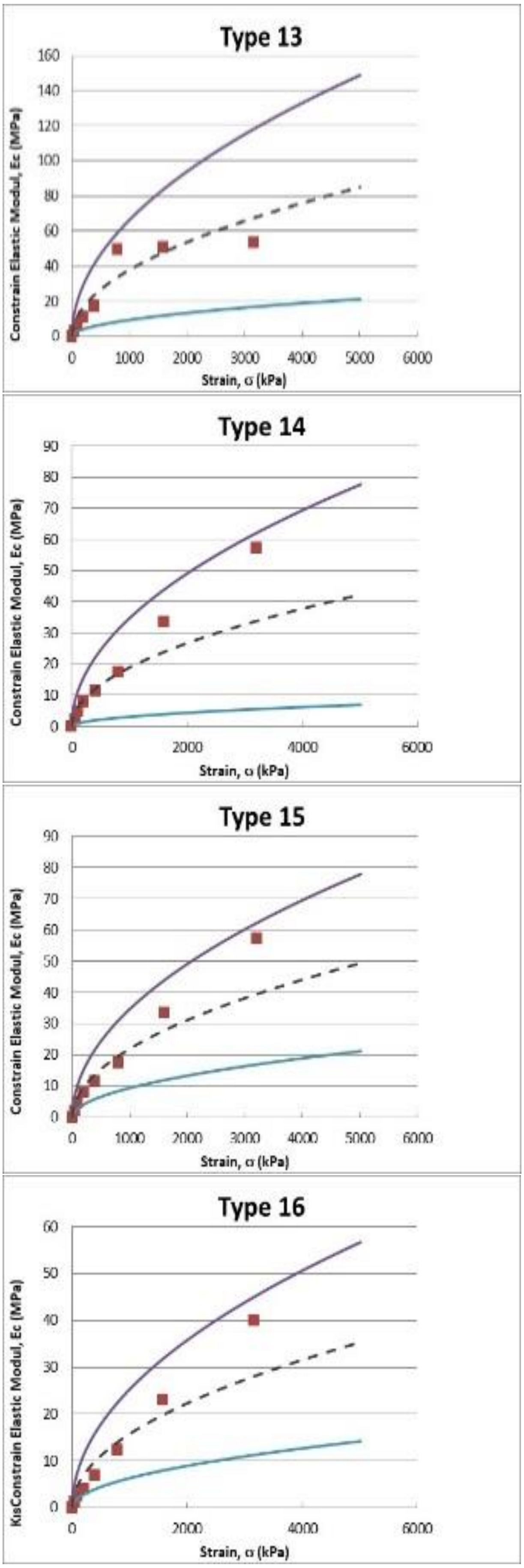

Figure 14. Constrained elastic modulus (Ec)–strain (σ) graphs for all sands (Type 13-16)

When the graphs were analyzed, it is seen that the original sands give higher Ec values relative to their derivatives.

4.3. Comparison of Shear Box Test Results for Griding Sand and Original Sand Samples

Shear box with experimental results are plotted charts (Figure 15)

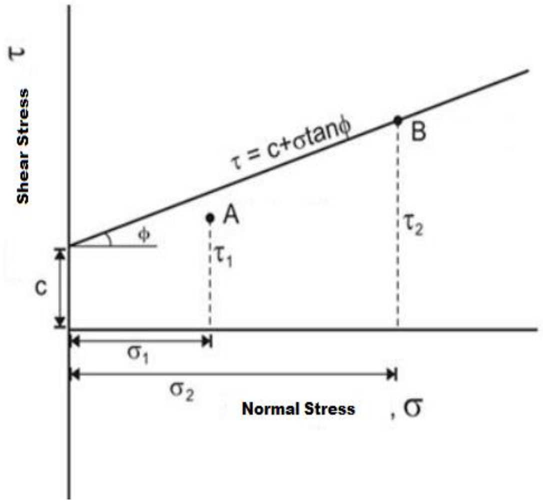

Figure 15. Shear box with experimental results are plotted charts

shearing stress;

$$\tau = c + \sigma \tan\phi \qquad (12)$$

τ: Shear stress
σ: normal stress
c: Cohesion
ø: Angle of internal friction

The sand used in the study was prepared with 40% density and 50, 100, 200 and 400 kPa loads were applied to them. Graphics of their comparison with the original sand are given in Figures 16-19.

C and ϕ values for the sands were calculated from the graphs (Table 8). The cohesion values of the grinded samples obtained from the Type 1 and Type 13 sands yielded lower values, while the cohesion for the other samples is different.

The internal friction angles of the samples obtained from Type 1, Type 5 and Type 9 (sea-derived sand) gave much higher values, while the samples obtained from Type 13 (stream-derived sand) gave similar or higher values.

The engineering properties of the samples changed with the reduction of the grain sizes of the sand.

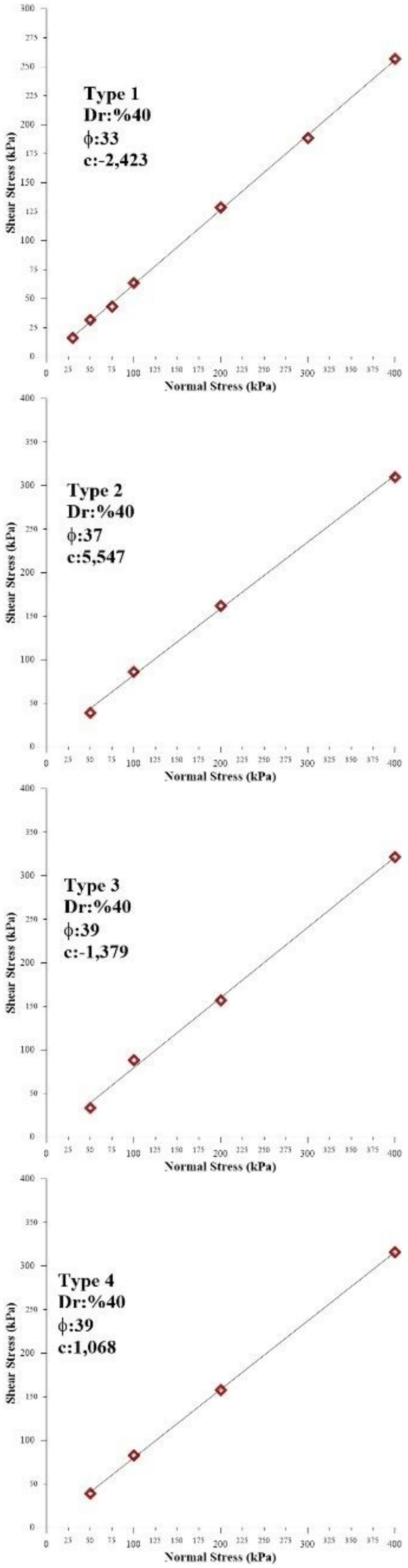

Figure 16. Shear stress–normal stress graphs of the original samples and the derived samples (Type 1-4)

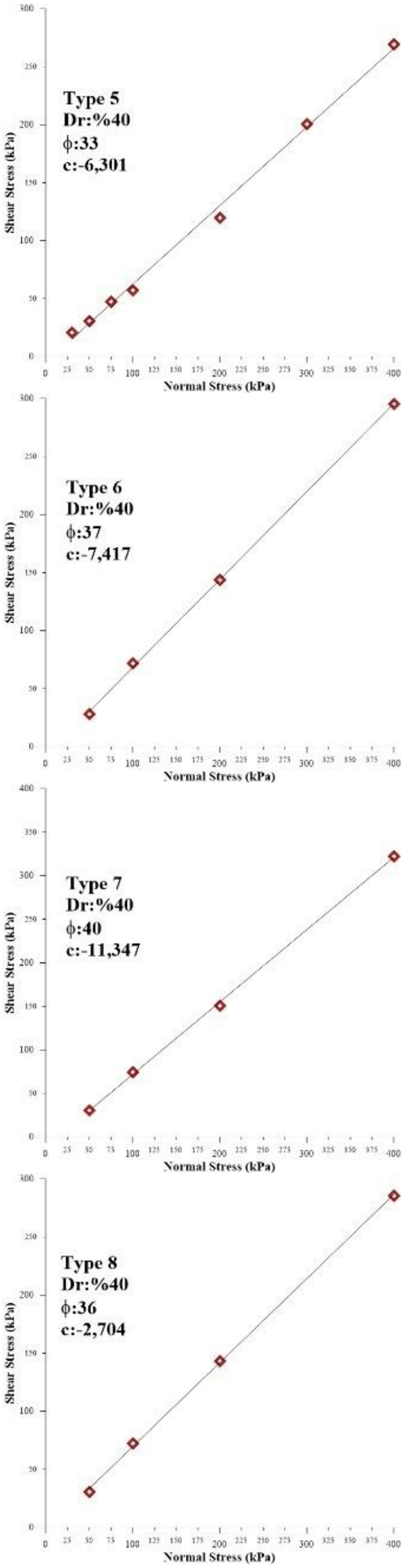

Figure 17. Shear stress–normal stress graphs of the original samples and the derived samples (Type 5-8)

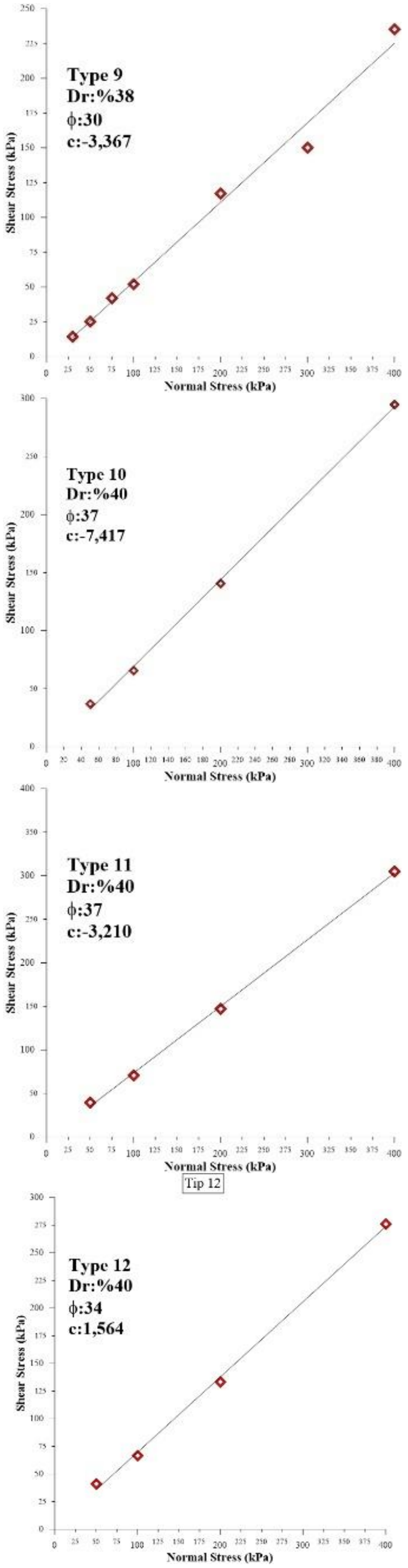

Figure 18. Shear stress–normal stress graphs of the original samples and the derived samples (Type 9-12)

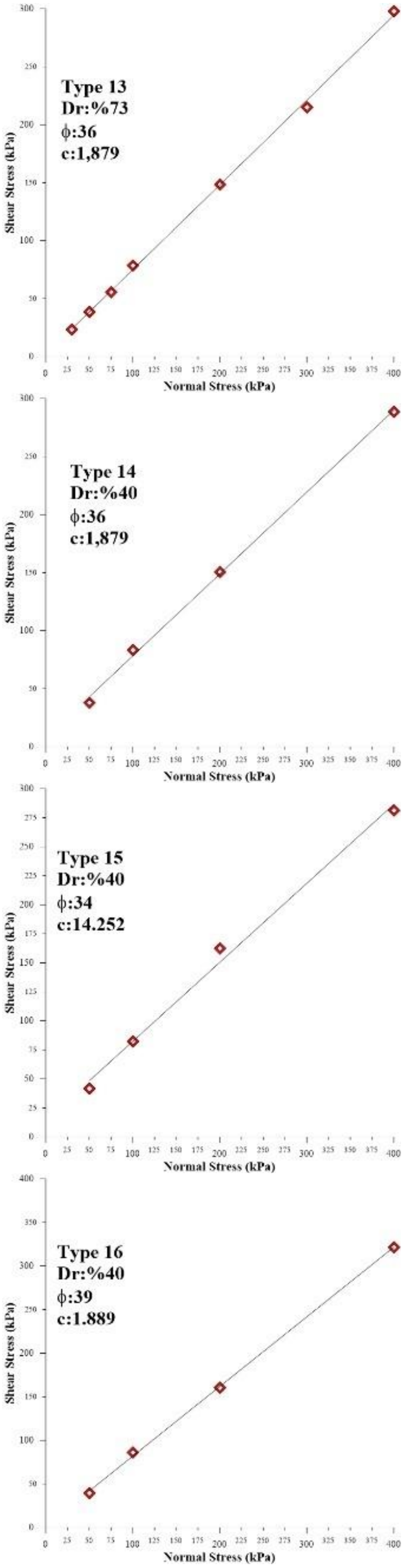

Figure 19. Shear stress–normal stress graphs of the original samples and the derived samples (Type 13-16)

Table 8. Changes in c and ϕ values according to low density values for all sands

Type	ϕ	c	Type	ϕ	c
1	33	−2.423	**5**	33	−6.301
2	37	5.547	**6**	37	−7.417
3	39	−1.379	**7**	40	−11.347
4	38	1.068	**8**	36	−2.704
Type	**ϕ**	**c**	**Type**	**ϕ**	**c**
9	30	−3.368	**13**	34	−1.603
10	37	−7.417	**14**	35	7.735
11	37	−3.210	**15**	34	14.252
12	34	1.564	**16**	39	1.889

5. Conclusion

In this study, the engineering behaviors of the sands and their griding derivatives were investigated by using shear box and consolidation experiments. Each of the sand samples was grinded to produce 3 different samples with specific grain sizes. The physical properties of the selected samples were determined by hydrometer and specific gravity experiments. During the study, it was seen that the Type 1 and Type 9 sand have a similar grain distribution and that Type 5 and Type 9 sands have similar mineralogical characteristics. Unlike the other 3 types of sand, Type 13 sand is taken from the stream bed and shows typical quartz sand properties.

It was determined that Type 1, 5 and 9 sands were composed of medium and coarse grains, and Type 13 sand was composed of fine and medium grains. By using the sieve analysis after the end of the experiments, it was determined that the change in grain percentages corresponded to the increase of fine and medium grains. It has been seen that the Type 1 and Type 9 samples have 60% middle grains and 40% coarse grains, that Type 5 sand has 88% coarse and 12% middle grains, and Type 13 sand has 11% coarse, 88% middle and 1% fine grains. The finest grained material is Type 13 and the coarsest material belonged to Type 5 sand.

The specific gravity values expected from regular sand vary from 2.60 to 2.75. The specific gravity of the sands used in the experiment varied from 2.74 to 3.44. Type 5, Type 9 and Type 13 sands had a specific gravity of 2.74 and 2.75 due to the muscovite content. Type 1 had a specific gravity of 3.44 due to the high content of the mineral augite.

The void ratio of the sands is usually from 0.5 to 0.9. The void ratio in the sand was not expected be less than 0.3 and not be more than 1.2. The minimum void ratios of the sands used in the study ranged from 0.520 to 0.600 and the maximum void ratios ranged from 0.781 to 0.927. Thus, these values (0.520 to 0.927) were positioned within the limits of the standard values. Type 13 (stream sand) had the largest void ratio value. The differences between the maximum and minimum values are represented as follows: Type 1 = 0.311, Type 5 = 0.261, Type 9 = 0.280 and Type 13 = 0.412.

Type 5 sand displayed great differences to its derivatives in the oedometer experiments. This sand contains coarse grains relative to other sands. In general, derivatives gave similar values to each other. During this study, the relationship between the volume change behavior and the first void ratio and void ratio change were also demonstrated. The effect of the first void ratio on the volume changing properties of the soil is undeniable. The study found that loose sand prepared with low compactness showed normal consolidated clay-like behavior. Although the sands taken from different regions have the same tightness, they display different deformation behavior at the same load level. Although the water content was not taken into consideration for the oedometer results on the sands, the values were calculated in order to follow the change in them. Type 1 sand, which has angular grains, had 23.01% water content and Type 13 sand had a water content of 24.64%. In addition, Type 5 sand had 25.27% water content and Type 9 sand had a water content of 25.71%. Oedometer experiments were performed and the results were compared for gridinged sands samples prepared with 40% tightness. All 4 samples gave higher values relative to their derivatives. The largest difference is seen for Type 1 sand, which differs in origin from the other three sand samples. The curves have been drawn according to the changes in the fine grains relative to the variations displayed in the grinding processes. Void ratios and stress graphs were also prepared. Here again, it was seen that the derivative sands gave lower values and displayed similar slopes to each other in comparison to the original sands.

Finally, the samples were prepared for undrained shear experiments and graphs were produced. The c and ϕ values of the sands were calculated from the graphs. Round particles were not found in all of the sands used in the study. This means that the samples did not extensively erode and they stayed close to their host area. Type 1 was the one with the most angular grain content of the samples taken from the seaside. Its mineral content causes higher strength relative to other sands. Type 13 sand was taken from the stream bed unlike the other three sands, which were taken from the coastline. Stream sand consists of more angular grains relative to sea sand. For this reason, the strength angle of Type 13 sand was higher than the other three sands. All four samples consisted of poorly sorted sand. For this reason, their strength angles were generally high. For all sands, especially at low tightness values, cohesion displayed negative values. The engineering properties of the sand changed according to their shrinkage in size.

Acknowledgements

This study was carried out as a post-doctoral study in METU DOSAP. I would like to thank Prof. Dr. Kemal Önder ÇETİN for his contributions.

Conflict of Interest

No conflict of interest was declared by the author.

References

Alagöz, T.,2008. The Relative Pressure Resistance of the Uneven Ankara Clay with Different Ratios of Sand and the Correlation of Direct Tensile Strength, Kırıkkale University, Master Thesis, Kırıkkale, Turkey.

ASTM D422-63(1998), Standard Test Method for Particle-Size Analysis of Soils, ASTM International, West Conshohocken, PA, ASTM D854 – 14, 2014.

ASTM D2487-11, (2011). Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), ASTM International, West Conshohocken, PA.

ASTM D4253-00 (2006). Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table, ASTM International, West Conshohocken, PA.

ASTM D 4254–00, (2006). Standard Test Methods for Minimum Index Density and Unit Weight of Soils Using a Vibratory Table, ASTM International, West Conshohocken, PA.

ASTM D 698, Standard test methods for laboratory compaction characteristics of soil using standard effort, Annual Book of ASTM Standards (1998), American Society For Testing and Materials. West Conshohocken.

ASTM D3080-98 (1998), Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions, ASTM International

ASTM D 4318, Standard test methods for liquid limit, plastic limit, and plasticity index of soils, Annual Book of ASTMStandards (1998), American Society For Testing and Materials, West Conshohocken

Aytekin, M, 2004. Experimental Soil Mechanics, 117 p, Technic Publish, Ankara, Turkey

Başer, O., and Çokça, E.,2010. Improvement Of Swelling Soils By Using Waste Marble Powder, Soil Mechanics And Foundation Engineering Thirteenth NationalCongress, Istanbul, Turkey, Batman, A., 2015. Investıgatıon Of The Effects Of Griding Quartz Sand Into The Strength Propertıes Of Clay. Atatürk University, Master Thesis, Erzurum, Turkey.

Bayoğlu, E.,1995. Shear Strength and Compressibility Properties Of Sand-Clay Mixtures. Middle East Technical University, Master Thesis, Ankara, Turkey.

Çanakçı, H. ve Güllü, H, 2007. Investigation Of The Effect Of Mixing Ratio On The Internal Friction Angle Of Clay-Sand Mix Soil, 2nd GeotechnicalS ymposium, Adana, Turkey, 430-436.

Çellek, S, 2016. Soil Mechanics Laboratory Experiments For Sand Samples, Lambert Academic Publishing, Turkey.

Çimen, Ö., Keskin, S., N., Şimşek, S., Kalay, E., 2010.The Effect of Pumice and Marble Powder on the Engineering Properties of a High Plasticity Clay, Thirteenth National Congress of Soil Mechanics and Foundation Engineering, Istanbul 855-862.

Dağdeviren, U., Güven, C., Gündüz, Z., 2008. TheEffect of Uniform Sand on Slip Resistance and Porosity of High Plasticity Clay. Twelfth National Congress of Soil Mechanics and Basic Engineering, Konya, Turkey, 345-354.

Durmuş, S., 2007. Investigation Of Slip Resistance Parameters Of Low Plastic Clay. Sakarya University, Master Thesis, Sakarya, Turkey.

Güven, C.,2007. Effects Of Sand Quantity On Slip Strength In A High Plasticity Clay. Sakarya University, Master Thesis, Sakarya, Turkey.

İkizler, S., B., Aytekin, B., Vekli, M., Yavuz, H., İ., Tandoğan, M., 2008.Stabilization of bentonite with cement, fly ash and sand, twelfth national congress of soil mechanic s and basic engineering, Konya, Turkey, 689-698.

Karabüyük, E.i 2001. Effect of using bentonite on geotechnical properties in stabilization of sandy soils, Atatürk University, Master Thesis, Erzurum, Turkey.

Kayabalı, K. 2010. Introduction to Geotechnical Engineering, 44p, Gazi Publish, Ankara, Turkey

Lade P V , Liggio C D Jr, ,Yamamuro J A 1998. Effects of Non-Plastic Fines on Minimum and Maximum Void Ratios of Sand. Geotechnical Testing Journal, GTJODJ, Vol. 21 No. 4, December 1998, pp.336-347.

Kumar, A., Walia, B. S. andMohan, J.,2006.Compressivestrength of fiber reinforced highly compressible clay", construction and building materials, Vol.20, 1063-1068.

Mollamahmutoğlu M. and Kayabalı, K. 2006. Principles and Applications of Geotechnical Engineering. 120-122p, Gazi Publish, Ankara, Turkey

Ölmez, M., S., Ergun, M., U.,2008. Shear Strength Properties of Clay - Sand Blends, Soil Mechanics and Twelfth NationalCongress of Basic Engineering, Konya, Turkey. 303-312.

Ünverdi, A.,2006. Effect of fine gravel content on slip resistance of high plasticity clay soils, gazi university graduate school of natural and appliedsciences, mastert hesis, Ankara, Turkey.

Vallejo and Mawby 2000. Porosity ınfluence on the shear strength of granular material-clay mixtures, Engineering Geology, 58, 125-136.

Wasti, Y. andAlyanak, I.1968. Effect of clay content on soil behavior. Civil engineering construction engineers chamberTurkey IV. technic congress, Ankara.

Yılmaz, M. K., and Çelik, S. 2012. Investigation of the effect of grinded sand on the swelling pressure and consolidation properties of clay soil. KSU. Journal of Engineering Sciences, 15 (2), 32-36.

Yılmaz, M. K. 2012. Investigation of effect of griding sand on swelling pressure and consolidation properties of clays. Atatürk University, Master Thesis, Erzurum, Turkey.

Zorluer, İ., and Usta, M., 2003.SoilImprovementandwastemarbledust, Turkey IV. Marble Symposium (Mersem), Proceedings Book, Afyon, Turkey.