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Effects of Microgrid Reinforcement on Soil Strength

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ABSTRACT: In geotechnical engineering geogrid materials are in use to reinforce the soil recently. When these materials are used together with the soil, the strength parameters of the soil increases. The usage of geogrids is also very profitable to improve the soil because the material is very economical, easy to apply and durable. Engineers needs some design parameters about this materials when used withsoils for geotechnical designs. Therefore, experimental studies that will enable these parameters to be determined are of great importance. In this study, triaxial compression tests were carried out under four different cell pressures(50, 100, 150, 200 kPa) in labarotory by using microgrids, which showss similar functions with geogrid. Soil samples were prepared without microgrid, single layer microgrid, two layers microgrid and three layers microgrid and each of them were individually tested in triaxial compression. 2 mm aperture sized grid reinforcement configurated in 50*100 mm in silty soil triaxial specimen as in layer form of one to three. In the experimental study, it was determined that the strength values of the soil samples using geogrid were higher than those without geogrid. It was also found that the most efficient reinforcement was the use of two layers of microgrid. One of the important findings was taht with the use of microgrid reinforcement, the strength parameters of the soil could be increased by % 307.

KEYWORDS: Microgrid, Reinforced Soil, Soil Improvement, Triaxial Compression Test

I. INTRODUCTION

In recent years geosyntetics widely used in geotechnical applications such as improvement of weak soils, retaining walls, slopes, road embankments e.t.c.. geogrid material main benefit is to give the soil tension capacity where soil has weak ability. Reinforcement material and soil works as a composite, maintains interlocking ability between soil and geosyntetic composite. Geogrid coils together with the soil particles that gives improved strength properties as a result[3].

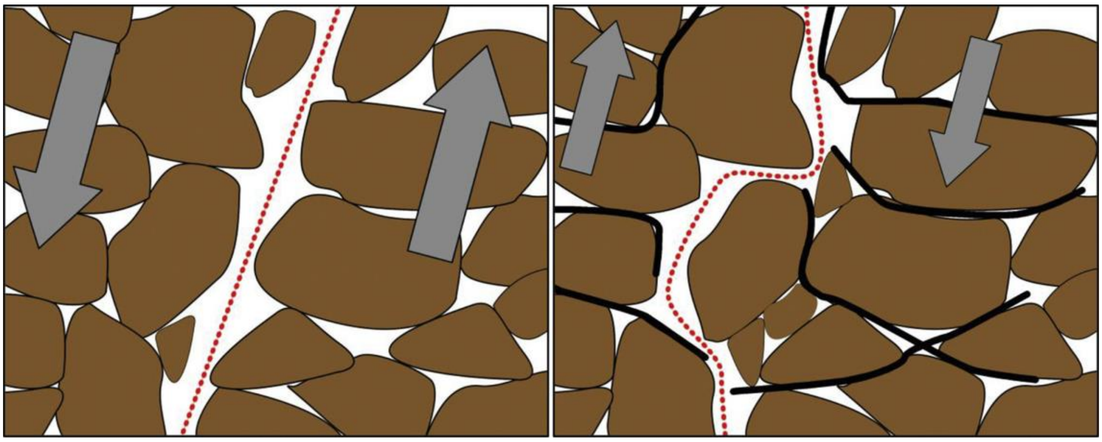


Fig.1. The Soil Matrix Reinforced with the Microgrids[3]

Before the application, geotechnical design engineer should have various values about the material of those. Geogrids are a member of geosyntetic family and this material covers the weak side of the soil which is tension[3]. When soil and geogrid gets together the new composite system would be more strength on the carried loads, performance, stability e.t.c.. In this study microgrid material which has a similar function with geogrids are used to represent designing of comparable analysis of geosyntetic materials before application in the site. Therefore it should be understood from the small scaled laboratory test to predict the behaviour of the geotechnical materials. According to this idea microgrid material and fine graded soil performed by triaxial compression tests at Osmaniye Korkut Ata University's geotecnical lab. Various studies have researched positive effects of geosyntetic material either by triaxial compression test or direct shear test. On those studies geosyntetics reinforced the soil by resulting more strength according to unreinforced soil[5]. Athanasoupolus[1] studied about the geotextile and sand mechanical behaviour, where he focused on soil grading and geotextile aperture size. Chanderesekaran et all[6]. Focused on efficiency of reinforcement configuration,. Latha and Murphy[7] tried to find best configurated layer location and number of various geosyntetic material layers by triaxial compression test. In this study they found that after a certain number of geotextile layers there is no efficiency on soil improvement. Gray and Maher[10] analyzed fiber inclusion on soil by triaxial compression test. They mentioned that fiber inclusion gave the soil more ductility. Dhawan et all[2]. Mentioned that if the reinforcement placement configuration stays at the rupture zone and suitable geometry, efficiency would increase. Leschinsky et all[3]. Gave results about the microgrid reinforced soil by triaxial compression tests. They mentioned that after a certain value of the microgrid weight there is no efficiency, even less deviator stress on the peak points. Mcgown et all[8] studied about, grain size distribution effect on the behaviour of geotextile reinforced soils by direct shear test. Krishnaswamy and isaac[9] mentioned by the dynamic triaxial test experiments as a result that, reinforced soil is less abliqued to liquify by dynamic forces. Also increased stability and ductility performance of the reinforced soil. Gray and Maher[10] mentioned by triaxial compression test results in their studies that; reinforcement in soil matrix resulted very much increasement in soil strength even in low cell pressure values. Maher and Ho[11]; included in their study between the 2.5-20 mm. length of polymer reinforcement to soil by weight ratio. Longer reinforcement particles resulted more ductility in soil behaviour but less peak deviator stress. Dhawan et all[2]. Mentioned in their studies that; reinforcement geometry in triaxial tests, result different because of the failure pattern of the soil. They layered the reinforcement angled in failure zone of the soil pattern and resulted higher peak stress and ductility performance. Leshchinsky et all[3]. Studied with the microgrid reinforcement because of the fitting sizes of the material. By triaxial tests they mentioned that, after a certain soil and reinforcement weight ratio reinforcement is not effective. Yang et all.[15] mentioned in their studies peak deviator stress value of the reinforced and unreinforced soil depends on the tensile capture behaviour of the geotextile which layered in the soil. In other words They focused on tensiling ability of the geotextile layers by triaxial and digital image processing techniques. Haeri et all.[16] studied about the different sample sized, geotextile reinforced sand reinforcement increased the peak shear strength and strain at failure; also reduces the dilation. But small sized samples are more effected by the reinforcment. Gali and Murthy[17] studied about the different types and layer configuration of the sand by triaxial compression test. They mentioned that cellular form of the reinforcement is more effective then the others. Monahar et all.[18] studied about the optimum tyre crumb ratio and energy absorbtion capacity of the reinforced soil. In their study they found that tyre crumb ratio by soil weight has a optimum value and tyre crumbs increased post peak behaviour axial strain at failure, energy absorption and ductility capacity. Altay et all.[19] studied about the pull out behaviour of the geosyntetic reinforced clay by direct shear test. They mentioned that pull out peak points are approxiamtely%30 higher then the interfacial behaviour of the clay. Also in optimum water content reinforced clay peak shear stress is %60 higher then the other water contents. Kayadelen et all.[20] studied about the pull out behavior of the sand by direct shear test they mentioned that relative density of the sand plays very important role in peak point, however pull out efficiency is very importantly depend on particle size and reinforcement aperture size. In this study microgrid material which has a similar function with the geogrid used in triaxial compression test as in 50,100,150,200 kPa cell pressures and up to 3 layer microgrid material as in 50*100 mm triaxial specimen.

II. MATERIAL AND METHOD

2.1. Material

All tests completed at Osmaniye Korkut Ata University geotechnical laboratory, undisturbed soil got from Osmaniye city fakiusagi region by borehole method. By applying the standard geotechnical testing methods soil classification and strength parameters has found. While finding gradation of soil hydrometer test Astm D7928[22] also used with sieve analysis because of the much fine grades in the soil. After particle size distribution atterberg limits Astm D4318[23] applied to the soil to define the soil location at plasticity card. Proctor test Astm D698[24] applied to find the optimum water content. After completion of index properties UU Triaxial compression test applied to soil to find out undisturbed soil strength properties.

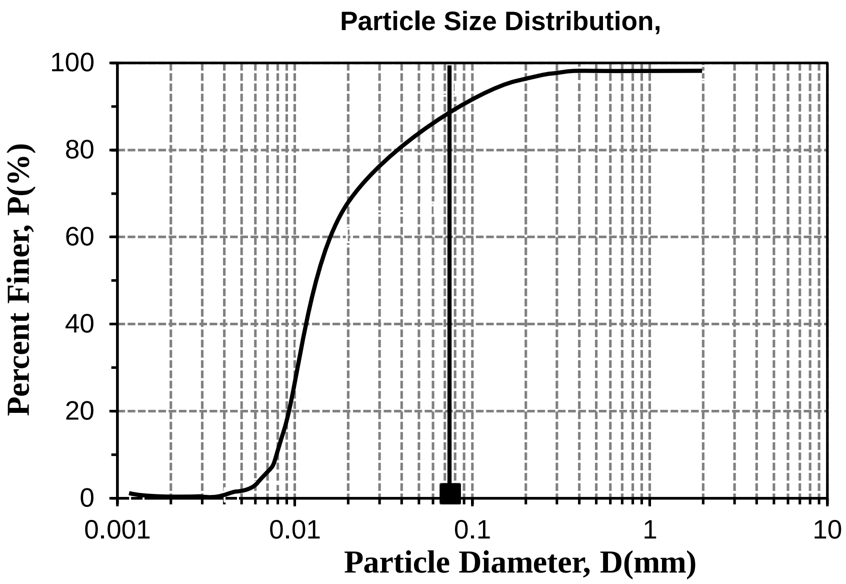


Fig 2. Particle Size Distribution of the Sily Soil

Fig 2. Shows that soil mainly consist of silty grain size distribution. Main index properties of the soil given at the table 1.

Fig 3. Hydrometer Experiment

In fig 3. Hydrometer photo is given, soil consist of mostly from the fine graded particles, to find out the particle size distribution under the No.200 sieve not only atterberg limit and casagrande card is enough.

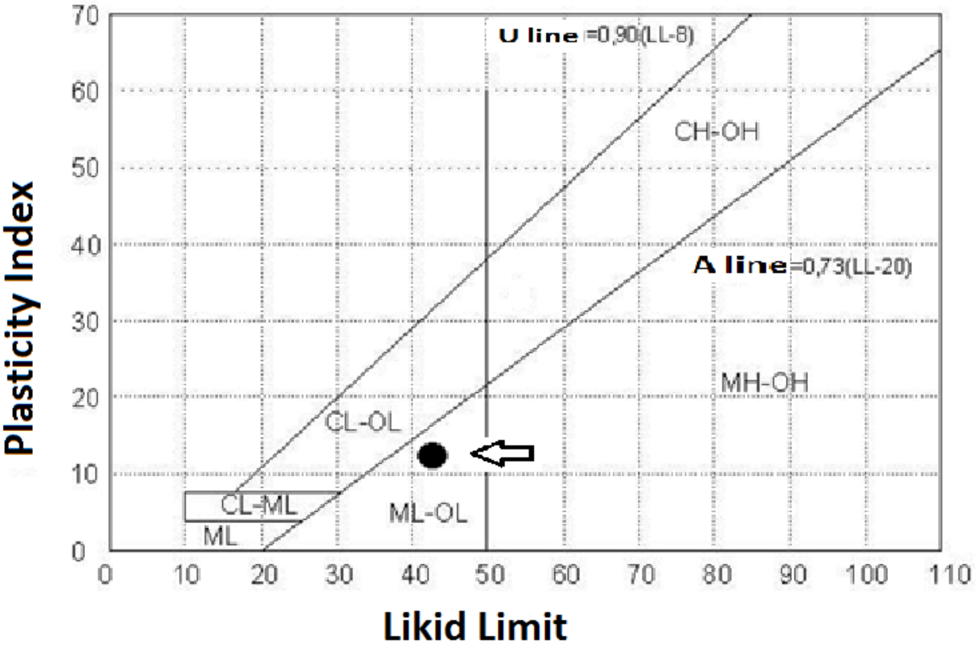


Fig 4. Casagrande Card of the Low Plasticity Silt

In fig. 4. Atterberg limits are given the definition side of the soil is ML,OL part, by combining hydrometer and casagrande card results and according to classification soil specimen found as "ML". On the table 1 details of soil properties has shown.

Table 1. Silty Soil Index Properties

Soil Specimen Properties		
Terms	Unit	Value
Cohesion (c)	kN/m^2	25.86
Internal Friction Angle (Φ)	°	15
Uniformity Parameter (C_u)	-	2.68
Curvature Parameter (C_c)	-	0.55
D_{10}	(mm)	0.0082
D_{50}	(mm)	0.015
D_{60}	(mm)	0.022
D_{30}	(mm)	0.01
Natural Water Content (ω)	%	21.6
γ_s	kN/m^3	2.68
γ_n	kN/m^3	2.03
e	-	0.59
γ_k	kN/m^3	1.68

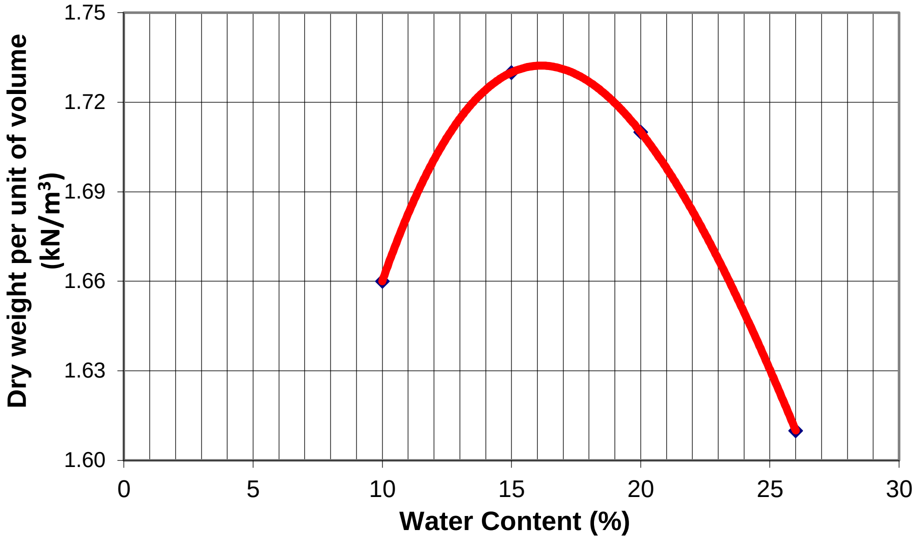
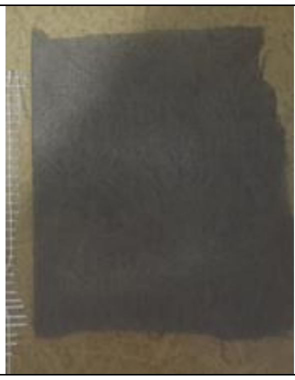


Fig 5. Proctor Curve of the Experimental Soil

According to proctor results given in fig 5. optimum water content is w_{opt}=%18. In the tests one type of microgrid reinforcement placed to represent the geogrid reinforcement. Microgrid grid length is 2 mm. And reinforcement properties are given in the table 2.

Table 2. Strength Properties of The Reinforcement

Microgrid Properties	
Microgrid	2 mm.
Weight (g/m²)	125
Thickness (mm)	0.2
Grid Length (mm)	2
Max. Tensile Force (N/m)	1200
Photo	

2.2. Method

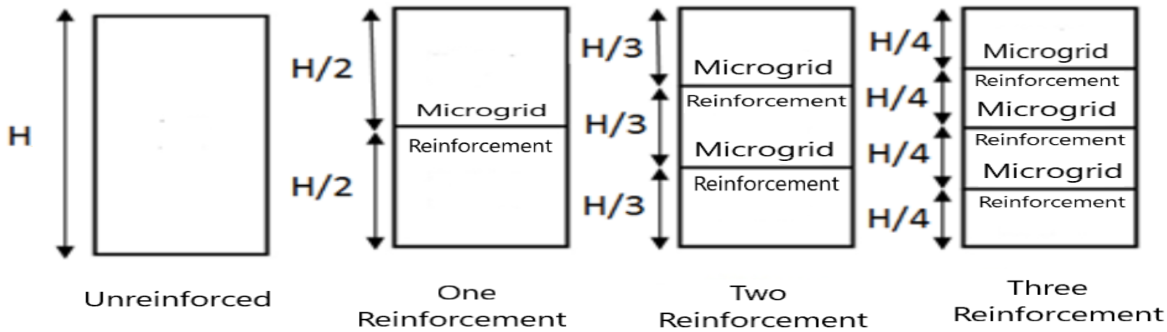


Fig 6. Reinforcement Configuration of the Experiments

Every reinforcement configuration experimented in four cell pressure such 50,100,150,200 kPa. Experiments done in natural moisture content which is %21.6. Total 16 pieces of unconsolidated undrained quick experiment helded. Sample size of the experiments is 50*100 mm. Reinforcement layered in the sample 49 mm. Diametered, for example after getting the labaratory, samples by UD tupes from the site, special sample cutter did the size 50*100 mm in the lab. For one layered reinforcement configuration 100 mm. Cut in half by the help of geotechnical spatula then reinforcement layered at the middle of the sample then other half togethered and 25 times hit given by sample preparator according to Ladd’s[21] advises where he has given a book about geotechnical sample preparation by Astm standards[21].

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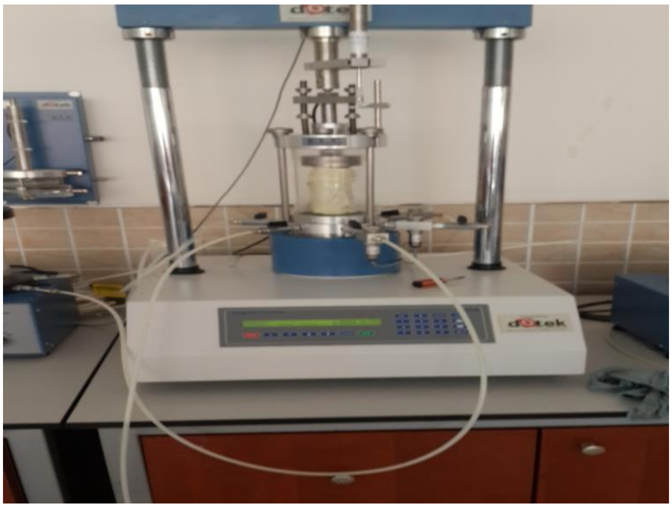

Fig 7. Triaxial Compression Test Used for the Study

In the tests, load speed selected as 1 mm/mn. According to Astm D2850[25] standard. In every test 40 times read is taken, even if the sample failured tests are continued to see the residual behaviour of the soil after peak stress. In figure 7 triaxial compression test machine showed.

III. RESULTS AND DISCUSSION

Deviator stress axial deformation graphs, under four different confining pressure and configuration of layers shown in figures 8, 9, 10, 11, 12, 13, 14, 15 therefore increasement both reinforcement layers and confining pressure resulted as increasement in peak deviator stress, similarly increasement in friction angle(Φ°), the main reason of this increasement is interlocking mechanism of the composite matrix of soil and reinforcement also tensile ability of the grid reinforcement. Qian et. All.[12] detaily mentioned in their studies, this interlocking mechanism of soil grains and grid reinforcements.When deviator stress axial deformation graphs compared with the reinforcement to unreinforced one initial slope of the graphs have less inclinement and for the peak deviator stress soil matrix need more axial deformation at failure point. This behaviour explains more ductile behaviour on reinforced ones. Also for the unreinforced configuration, compared to reinforced one, behaviour of the soil in small strains resulted more deviator stress values, Tafreshi and Asekereh[5] explained the situation; unreinforced configurations has more brittleness, less ductility behaviour, this behaviour result more deviator stress values in small strains.

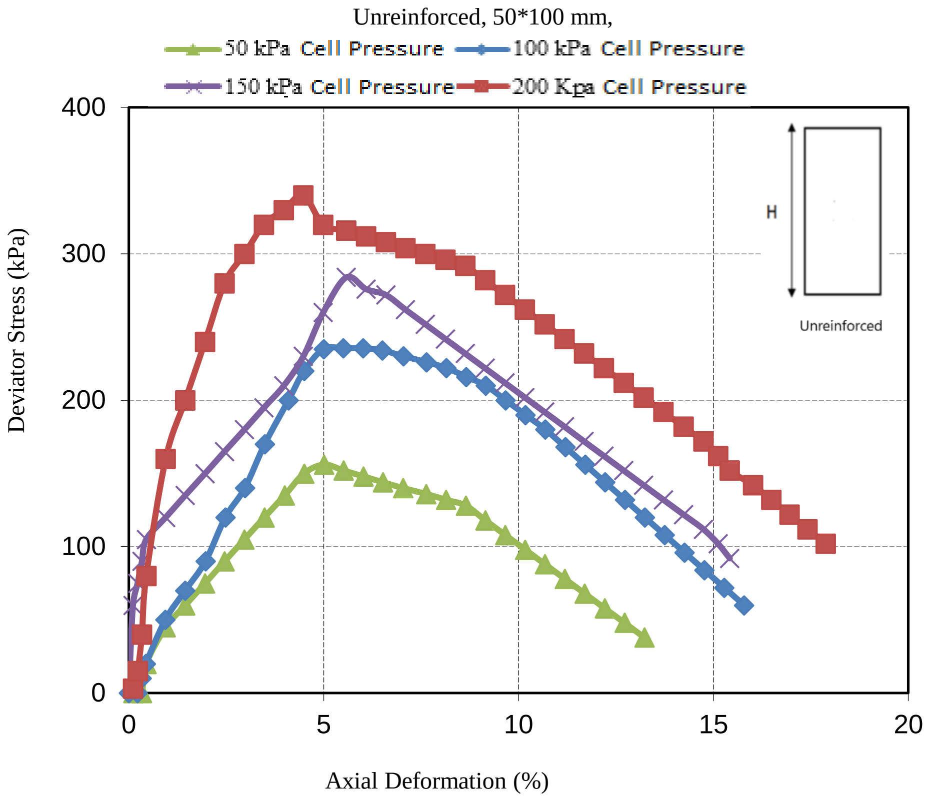

Fig 8.Unreinforced Samples Stress-Strain Curves

In figure 8. Unreinforced behaviour of soil can be seen, increasement in cell pressure resulted as, increasement in peak deviator stress. There is no improvement in post peak failure by increasement in cell pressure.

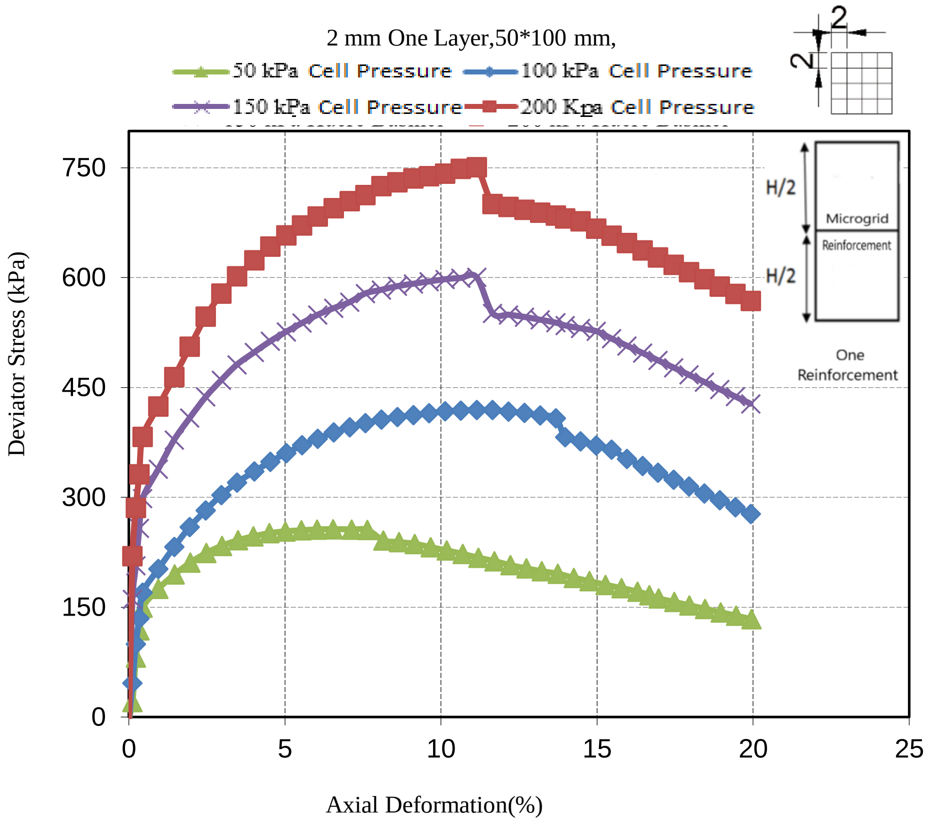

Fig 9. One Layer Reinforced Sample Stress-Strain Curves

In fig. 9 One reinforcement configuration in soil resulted as more ductiled, less lose of post peak strength and soil needs more strain values to get failured according to unreinforced one.

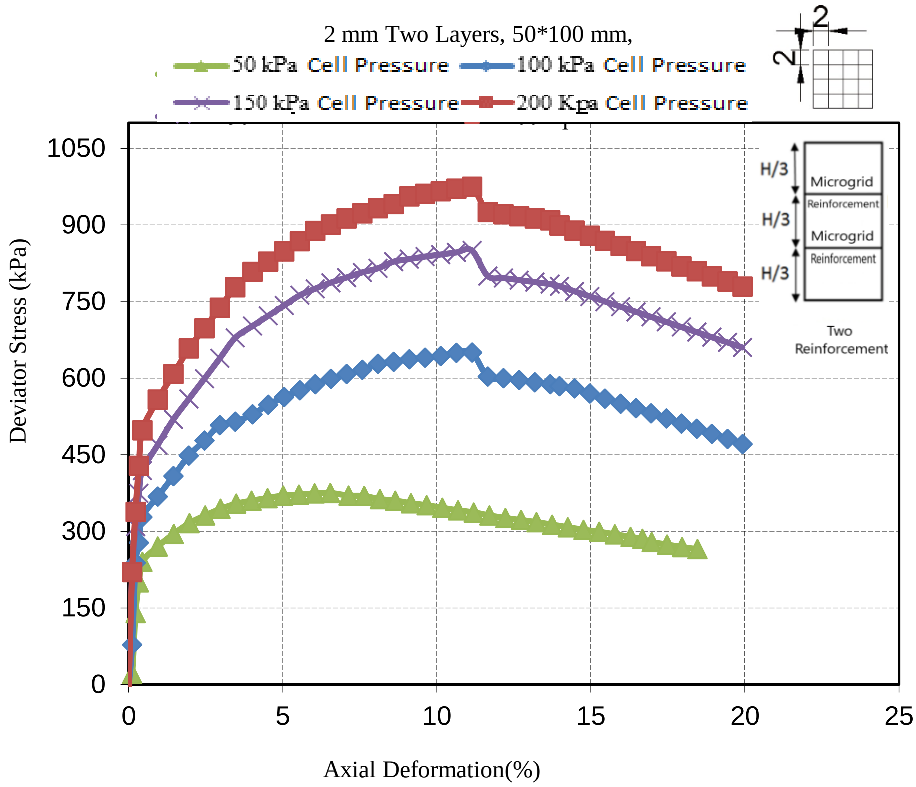

Fig. 10. Two Layered Reinforced Sample Stress-Strain Curves

In fig. 10 By adding reinforcement in soil configuration failure peak point values increased. This increasement is related to reinforcement confinement in soil matrix.

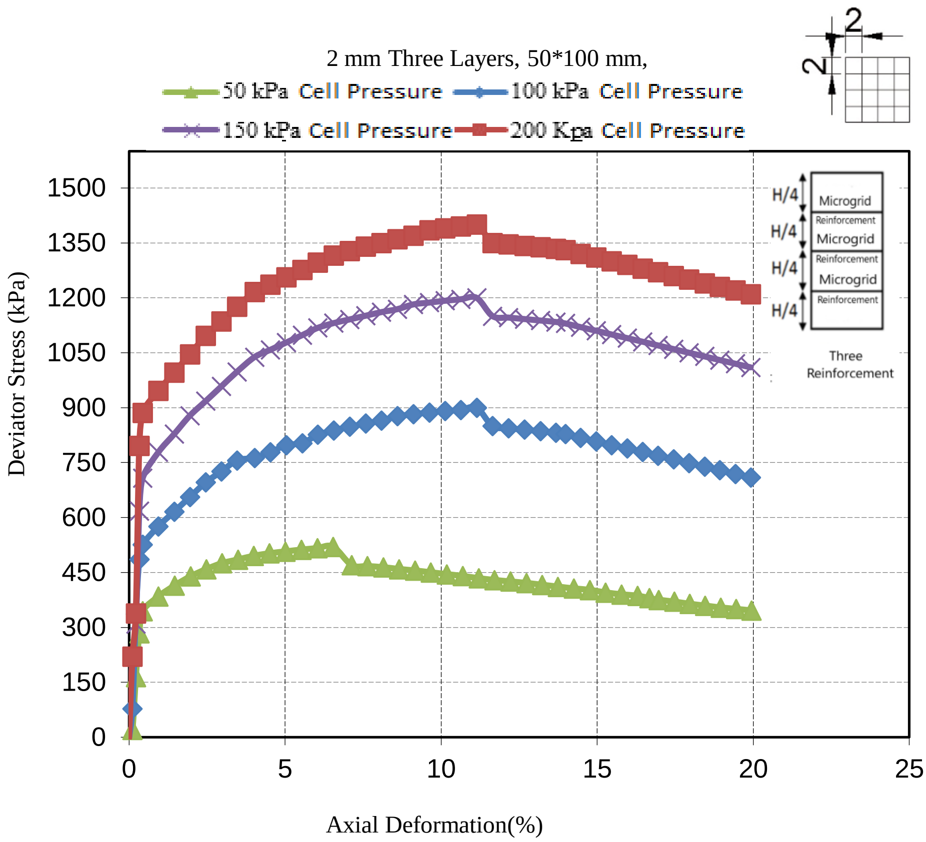

Fig. 11. Three Layered Reinforced Samples Stress- Strain Curves

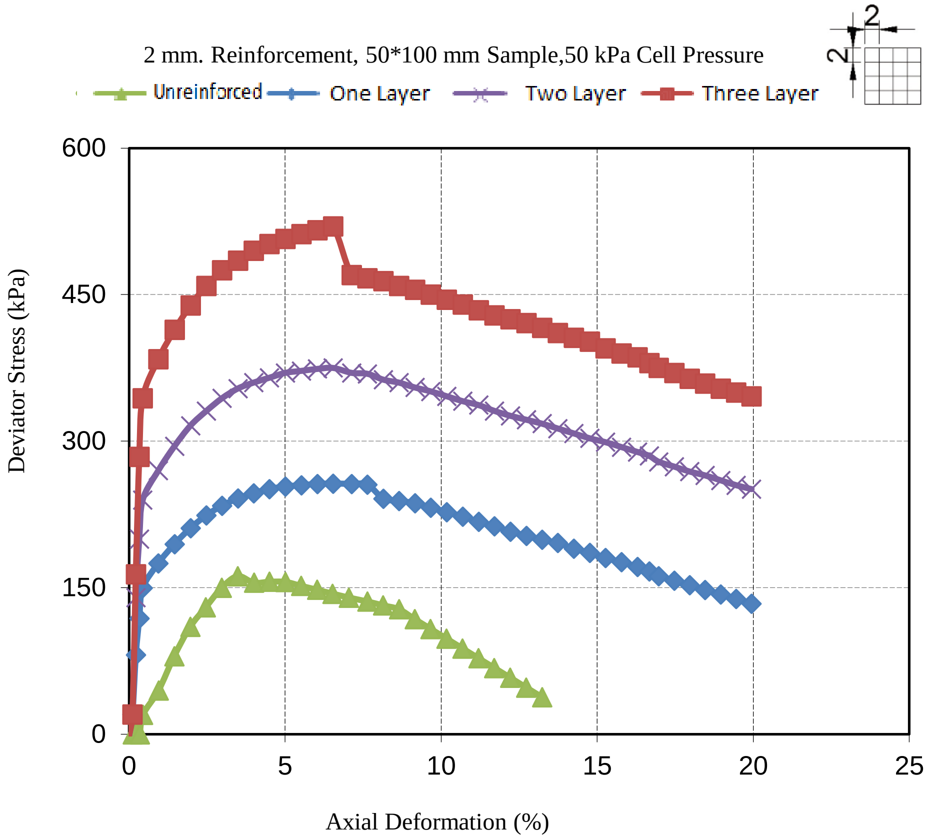

Fig. 12. 50 kPa Cell Pressured Stress- Strain Curves of Every Configuration

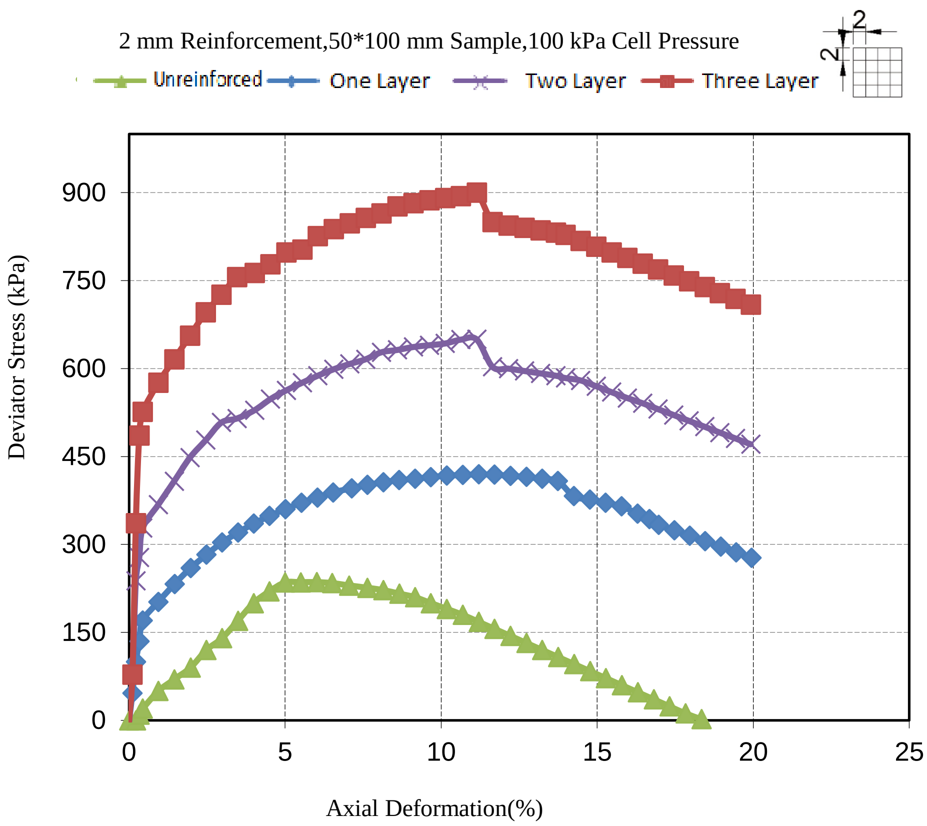

Fig. 13. 100 kPa Cell Pressured Stress- Strain Curves of Every Configuration

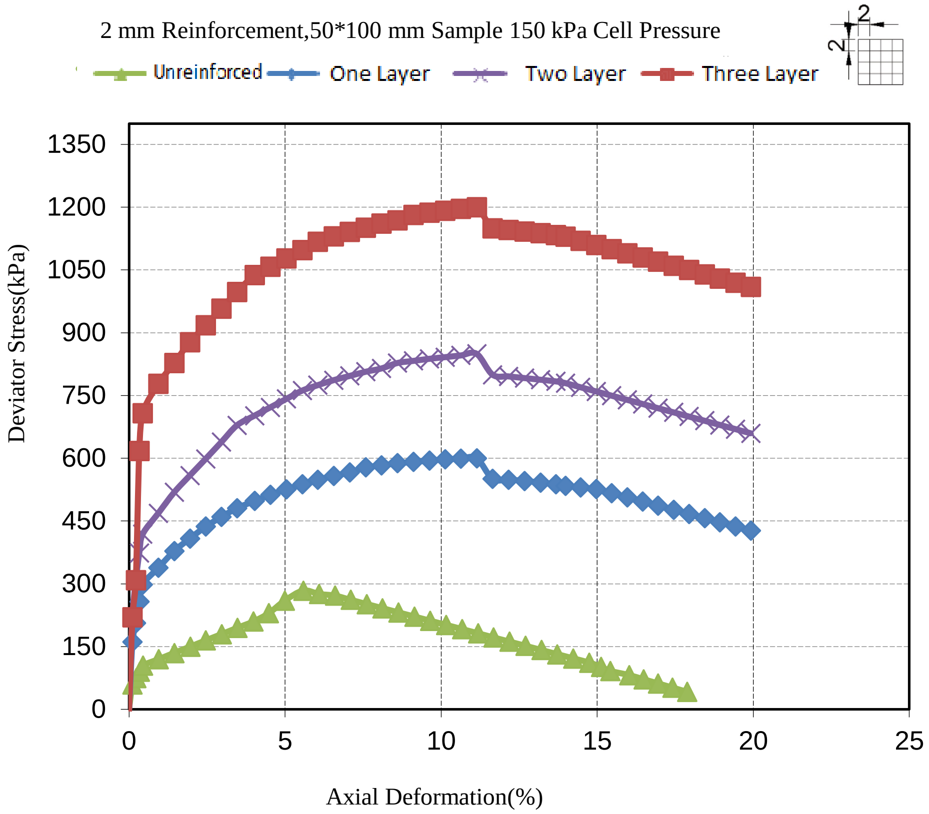

Fig. 14. 150 kPa Cell Pressured Stress- Strain Curves of Every Configuration

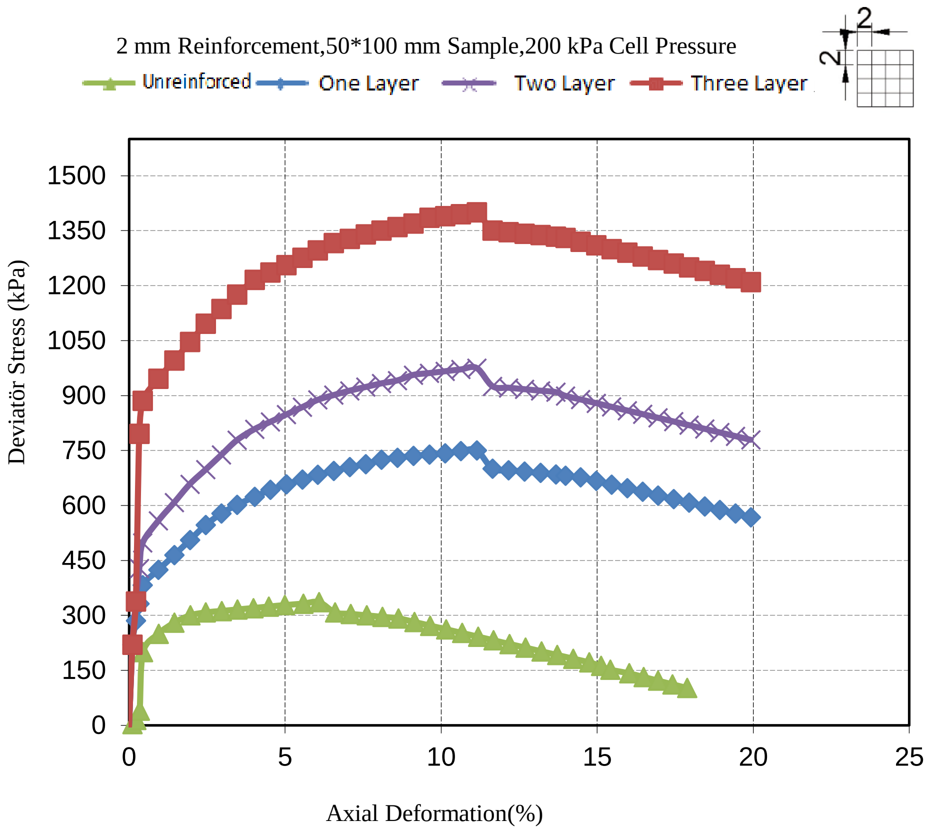

Fig. 15. 200 kPa Cell Pressured Stress- Strain Curves of Every Configuration

3.1.Effect of reinforcement configuration and cell pressure on deviator stress values

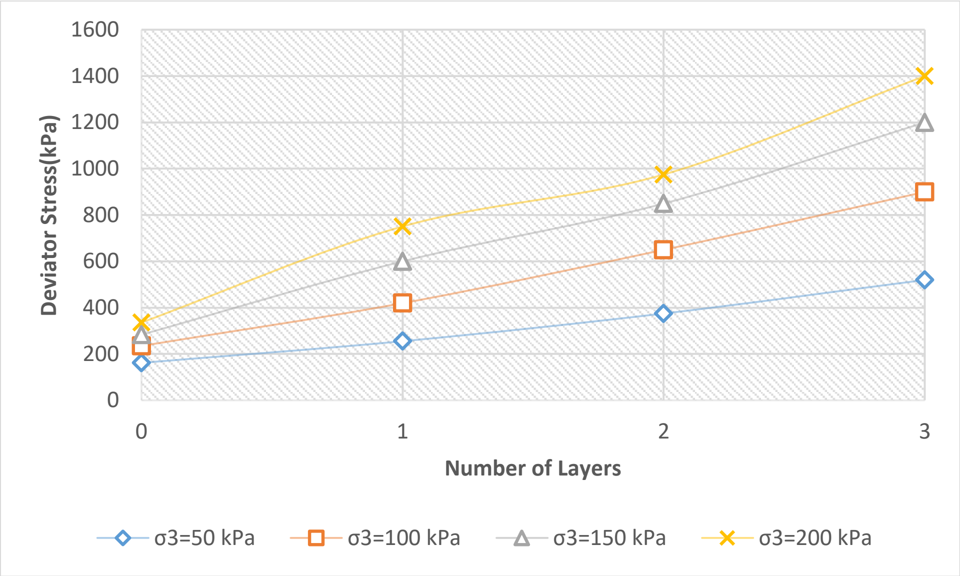

Fig. 16. Effect of Number of Layer Configuration

Increase in the grid layers resulted as increase in the peak point value of the deviator stress. Increasement untill the 2 number of layers goes linearly but when layer number becomes 3 its large amount of increasement in deviator stress. Mentioned that there is a optimum amount of geosyntetic weight ratio by weight of the soil according to site projects which considers factor of safety.

3.2.Effect of Cell Pressure on Deviator Stress

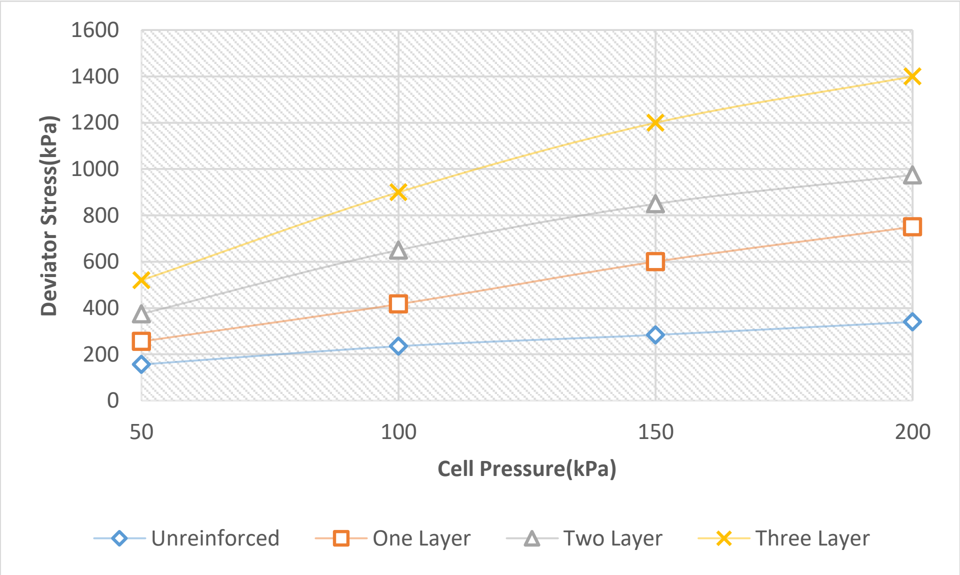

Fig. 17.Effect of Cell Pressure on Peak Deviator Stress of Soil

Increasement in cell pressure also resulted in increasement in deviator stress, but increasement is not similar like in the fig. 16. In other words values are not vaulting, because confining stress is littly interrupting the grid-soil matrix and grid effects are reducing in high cell pressures.

3.3. Effect of Reinforcement Configuration on Different Strain Levels

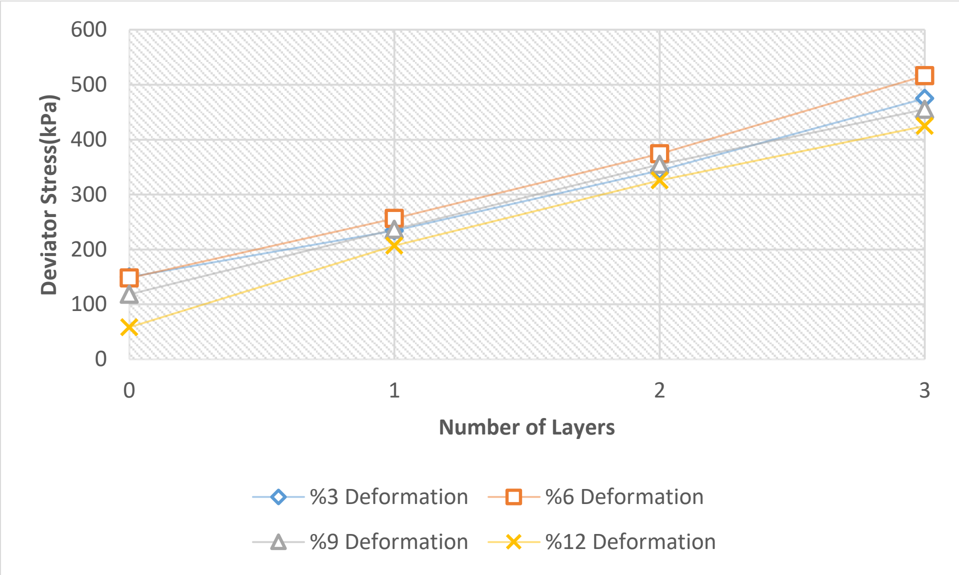

Fig. 18a. Under 50 Kpa Cell Pressure,Deviator Stress Values of Different Deformation Rounds

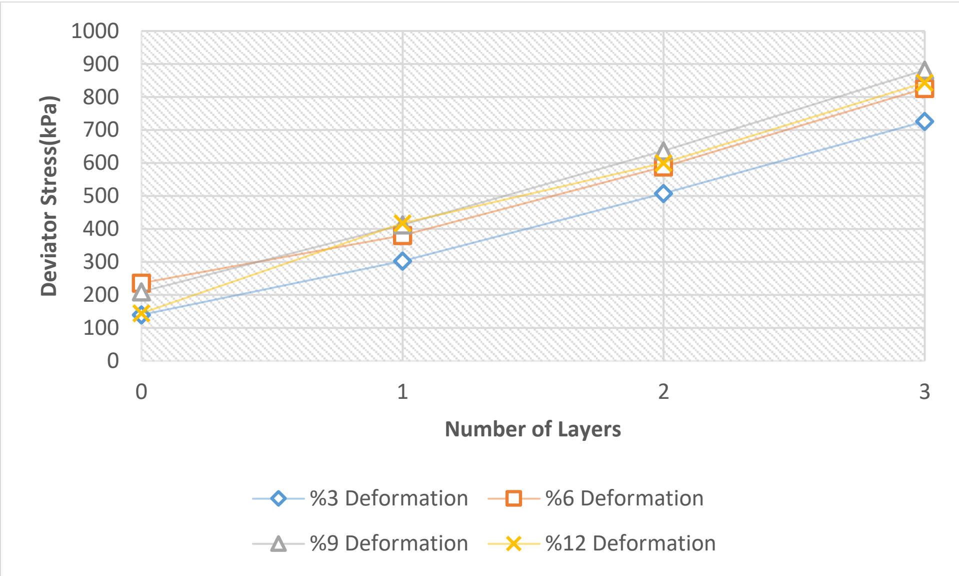

Fig. 18b. Under 100 Kpa Cell Pressure,Deviator Stress Values of Different Deformation Rounds

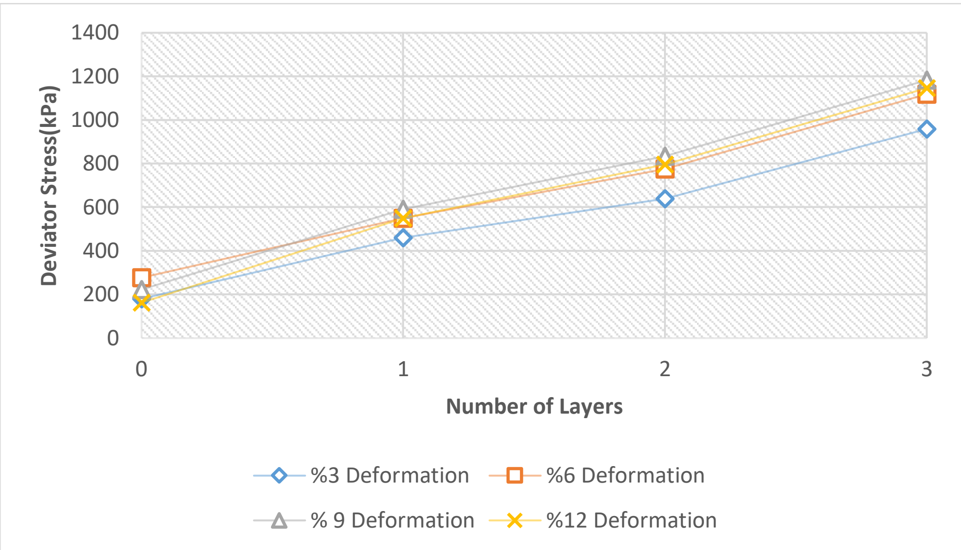

Fig. 18c. Under 150 Kpa Cell Pressure,Deviator Stress Values of Different Deformation Rounds

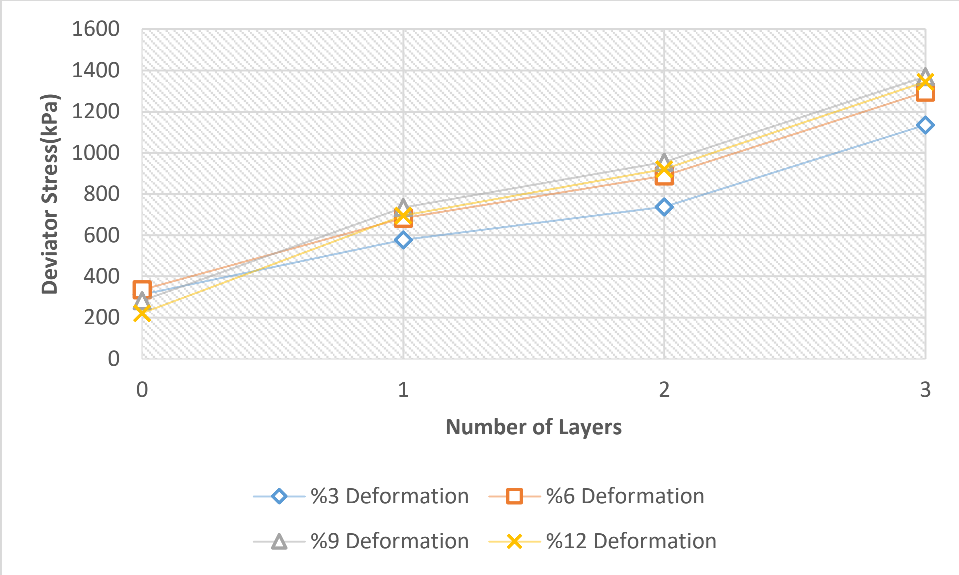

Fig. 18d. Under 200 Kpa Cell Pressure,Deviator Stress Values of Different Deformation Rounds

Fig 18 a,b,c,d is about deviator stress number of layers at different strain values %3 to %12 for different cell pressures of 5,100,150,200 kPa. If cell pressure values are divided into two such low and high, low ones are 50,100 high ones are 150,200 kPa. At low ones deviator stress increases linearly for lower to upper strain values according to number of layers. But in high cell pressure values deviator stress vaults when number of layers becomes 2 to 3. In high amount of grid layers soil fails at more higher deviator stress. This is about the ductility behaviour of the grid-soil matrix.

3.4.Effect of Reinforcement Configuration on Strain at Failure

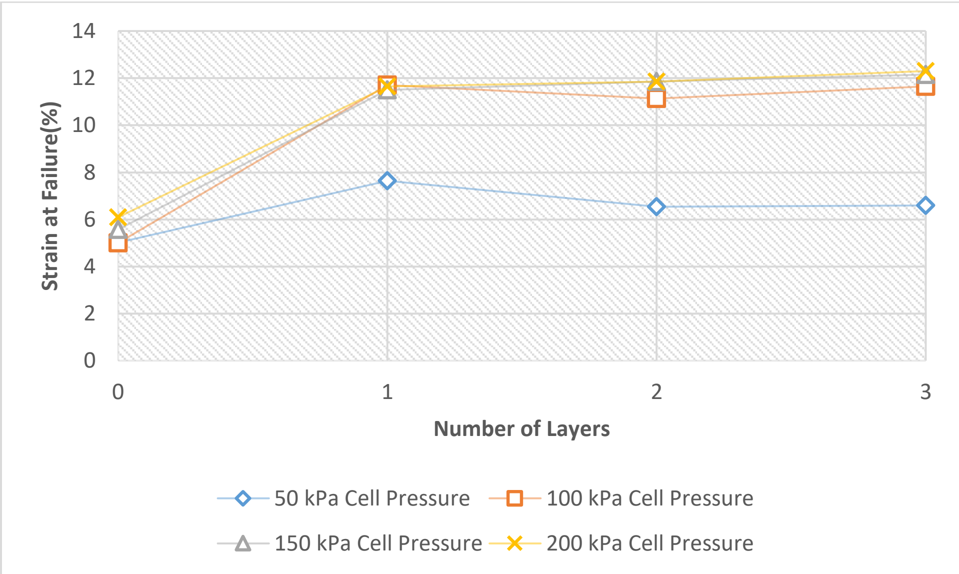

Fig. 19. Failure Strain Values of Every Layer Configuration Under Different Cell Pressures

Fig 22. Shows the effect of grid layers on different cell pressures, In the figures it is clear that when grids are added strain at failure increases. In other words soil fails at higher amount of deformations. Esspeacilly when soil haves small amount of grid, strain values are vaulting.

3.5.Peak Strength Ratios According to Different Cell Pressures

Table 3. Peak Strength Ratio of Reinforced Soil for Different Cell Pressure Values

2 mm Reinforcement Peak Strength Ratio			
Cell Pressure kPa	One Layer	Two Layer	Three Layer
50	1.64	2.40	3.33

100	1.79	2.76	3.82
150	2.11	2.99	4.22
200	2.21	2.87	4.12

As seen in the table 3. strength ratio increased according to increasement in number of layers. High number of layer configuration(2 and higher) and high values of cell pressure resulted, decreasing in strength ratio, main reason is, in higher confining pressure values soil and reinforcement is slowly losing together working ability. In other words reinforcement is lessly active for covering tensile part of the soil, because of the high confining. Noorzad and Mirmoradi[13] studied with more reinforcement configuration and higher cell pressure values in compare to this study, and mentioned about this situation; mainly, in less reinforcement layer configurations at higher cell pressures soil has own strength. In higher reinforcement configuration, higher cell pressure soil and reinforcement interacts less then the opposition reinforcement configuration.

3.6.Effect of Reinforcement Configuration on Strength Parameters

Table 4.Strength and Improvement Parameters of Every Layer Configuration

Type of Specimen		**Shear Strength Parameters**		**Shear Strength Parameters Improvement Values**	
Aperture Gap	Reinforcement Configuration	Internal Friction Angle(ø), °	Cohesion(c), kPa	Improvement Factor(ø),°	Improvement Factor(c), kPa
2 mm	Unreinforced	15	25.86	1	1
	One Layer	36	28.28	2.4	1.09
	Two Layer	43	39.29	2.87	1.52
	Three Layer	46	19.85	3.07	0.77

As seen in the table 4. According to increasement in reinforcement configuration fi and c also increased. This increasement is very efficient for one layer configuration, situation explains soil needs very muchly to cover its weaken side which is tensiling capacity. Also one layer configuration is in soil failure plane where failure geometry is in cross position. Layer configuration is very efficient when it is in the failure plane[2].

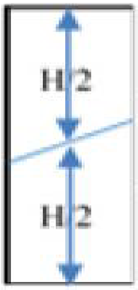

Fig.23. Reinforcement Geometry On Failure Plane[2]

According to literature cohesion depends on, grain size distribution, moisture ratio, reinforcement type e.t.c. As mentioned in this study one type of reinforcement has been used. Cohesion values increased until two layered configuration but in the third one, cohesion value reduced. Laman and Keskin[14] explained this situation more foreign inclusion in soil matrix, results reducing cohesive bond where fine graded soil own.

4. RESULTS

In this study, experiments of the grid reinforced silty soil is evaluated to observe the improvements of the soil by grid inclusion. Microgrid reinforcement selected because geogrid dimension is hard to fit triaxial test dimensions which is 50*100 mm. According to literature 2 mm. Microgrid reinforcement configurated such unreinforced, one,two,three in four different cell pressures 50,100,150,200 kPa.

- All reinforcement configuration resulted increasement in deviator stress in all cell pressures compared to unreinforced one.
- Strength parameters highly effected by the reinforcement configuration, esspeacilly number of two layers is most efficient one. Because at this point reinforcement- soil interaction is at highest point, in the notion of ductile and interlocking behaviour. More reinforcement reduces cohesion values and resulting more brittle behaviour even the increasement of deviator stress.

- Post peak values lessly reduces in reinforced soil compared to unreinforced one. Residuel stress is more stabilized at increasing strain values. This behaviour is more ductile and more long term stabilized improvement.
- Increasement in number of layers resulting in increasement in ductility and less brittle behaviour of the soil matrix.
- Strain values at failure point is higher then the unreinforced one. By this behaviour grid-soil composite is more strenghten for more deformations.
- Increasing in Maximum shear stresses is related to interlocking behaviour of the soil-reinforcement matrix. When the reinforcement-soil friction increases max. Deviator stress increases. Also soil fails at more strain values. According to this there is a optimised grid aperture size- soil grain size, which should be considered for future studies.
- Reinforcement soil configuration should done according to efficiency principle of optimized reinforcement soil weight ratio, also most efficient configuration or geometry should selected. Because if the reinforcement stays in failure plane of the soil it would be more efficient, in respect to weak tensile abilty of the soil where reinforcement covers.

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