EFFECT OF ENGINEERING PROPERTIES OF THE SAUDI ARABIAN SAND ON THE STRENGTH CHARACTERISTICS

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1. ABSTRACT

There are many projects that need to be constructed on sandy soil in the kingdom of Saudi Arabia. The purpose of this paper is to study the effect of grading and density of sand on shearing resistance and compressibility characteristics. The relationship between the angle of shearing resistance and the modulus of elasticity under different conditions is investigated. The effect of relative density and uniformity coefficients on the shear strength of the sandy soil for dry and submerged conditions were studied. The shear test is performed in the direct shear box under various normal stresses. The angle of shearing resistance corresponding to the peak state is determined for all conditions. The modulus of elasticity is determined from the oedometer test results. It was found that in the dry state of the soil, the void ratio is inversely proportional to the angle of shearing resistance and the modulus of elasticity. It was also found that the submergence state decreases slightly the angle of shearing resistance and the modulus of elasticity at the same void ratio.

2. INTRODUCTION

There are many areas in the Kingdom of Saudi Arabia consist of sandy soil specially in the coastal zones and desert, and many projects need to be constructed on the sandy soil in these areas. The purpose of this research is to study the shearing resistance and compressibility characteristics of that sandy soils.

Four different samples were prepared with different values of uniformity coefficients and constant values of effective diameter. All samples were tested at different relative density under both dry and submerged conditions. The shear tests were performed in the direct shear box under various normal stresses as well as the compressibility of these four samples. Stress-strain curves were plotted from the shear test results for different normal stresses and the angels of shearing resistance corresponding to peak state were determined for all samples. Stress-strain curves were also plotted from the eodometer test results and the tangent modulus of elasticity was determined.

Kirkpatrick (1965) studied the influence of grain size and grading on the shearing behaviour of granular materials from the results of drained triaxial tests. The influence on the angle of shearing resistance of grain size alone was investigated.

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3. SHEARING RESISTANCE OF SAND

The shear strength of soil may be defined as the maximum resistance of the soil to shearing stress under any given condition. The conditions referred above are mainly concerned with the drainage properties of the soil. For sandy soil, drainage is normally good and the rate of testing is unimportant factor. The failure of sandy soil is essentially controlled by friction and is proportioned to the effective normal stress. Typically, results that would be obtained from loose and dense sandy soil are shown in figure (1).

With loose sand the shear stress increases monotonically with displacement to ultimate constant value, while with initially dense sand the shear stress reaches a peak value before dropping to approximately the same ultimate value. The value of angel of friction corresponding to the ultimate condition depends on the mineralogy, roughness and grading of the soil particles. The peak value depends, on the initial density and the stress level, being greatest when the soil is initially very dense and the stress level is low (Milligan and Houlsby, 1984; Lamb, 1969; Kirkpatrick, 1965). A series of comparative tests has been performed using the commonly accepted triaxial and direct shear methods. The object was to evaluate the direct shear tests as a practical tool for measuring peak, effective shear strength parameters for design purposes.

Been and Jefferies, 1986; Christos, A. and Benjamin,W. 1982, studied the influence of grain size and grading on a shearing behaviour of granular materials. The influence of the particle size on the angle of friction shown in the figure (2) which indicates that the angle of friction increases as the grain size decreases. Also it is apparent that a better distribution of particle size produces a better interlocking and a higher angle of shearing resistance (Smith, 1981).

4. COMPRESSIBILITY OF SAND

The compressibility of soils caused by stresses less than those required to cause failure is important because it may give rise to deformations of the soil which directly affect engineering structures, and also because the strength of soil is affected by its density and will increase with compression. The stress-strain take place during the compression of all granular soils, although seldom in such distinct stages. Minor crushing and fracturing of particles actually begin at very small stresses, but become increasingly important when some critical stress is reached. This critical stress is smallest when the particle size is large, the soil is loose, the particles are angular, the strength of the individual mineral particles is low and the soil has a uniform gradation. In most engineering problems, the stress levels are usually small enough so that particle crushing is relatively of no importance. The time factor during the compression of sands is of no practical importance. Figure (3) shows the behaviour of several sandy soils during one-dimensional compression (Kirkpatrick, 1965). It shows that for large stresses, the secant modulus tends to become constant or many even decreases. For a given relative density, the modulus of an angular sand will be less than that of rounded sand. The modulus decreases as the particle size leads to a larger void ratio for a given relative density. Also increasing the uniformity of sand would decrease its secant modulus and increase its compressibility (Graham and Lau, 1988).

5. EXPERIMENTAL WORK

Sand samples with different grading and densities were tested in the shear box apparatus and oedometer to study the effect of grading and density on the angle of shearing resistance and modulus of elasticity of sand.

The effect of submergence, to the sand samples, and the shearing resistance and compressibility characteristics of tested sand were also studied.

5.1 Preparation of samples

Four different grading were prepared with constant effective diameter of 0.25mm. The grain size distribution curves for the four samples are shown in figure (4). The specific gravity of these samples were determined and found to be 2.67. The minimum and maximum void ratio, curvature and uniformity coefficient are given in Table (1).

5.2 Tests

All samples listed in table (1) were tested at different relative density (Dr=0.2 , 0.4 and 0.8) under both dry and submerged conditions, three direct shear tests were performed with different applied normal stresses (0.5 , 1.0 and 1.5 kg/cm2). For oedometer tests, the stresses of the dry samples applied were (0.5 , 1, 2 , 4 , 6 , 8 , and 10). The saturated samples were first placed into the ring in the dry condition and loaded up to 0.5 kg/cm2 , then the water was added carefully at this stress. The test was continued using the above stresses values.

Table (1): Physical Properties of Tested Samples.

Sample Designation	Maximum Void Ratio	Minimum Void Ratio	Effective Diameter	Uniformity Coefficient	Curvature
S 1	0.71	0.455	0.25	5.6	1.92
S 2	0.764	0.47	0.25	3.2	1.513
S 3	0.82	0.56	0.25	1.657	0.894
S 4	0.89	0.66	0.25	1.32	0.819

6. RESULTS AND ANALYSES

6.1 Shearing Resistance of Sand

The angle of shearing resistance of sand is studied in the terms of the voids ratio, relative density and the uniformity coefficient for sand samples. Figure (5) shows the relationship between the angle of shearing resistance and the void ratio for different relative densities tested in the dry and submerged conditions. It is noticed that increasing the void ratio leads to a decrease in the angle of shearing resistance. Also it is noticed that in the submerged condition the angle of shearing resistance decreases slightly compared to dry condition for the same void ratio. The obtained results are compared with the values of angle of shear resistance (ϕ) given by Lambe (1969) for different void ratios. It is shown that Saudi tested sand gives higher (ϕ) value. This is due to particle shape and probably mineralogy.

Figure (6), it is noticed that the relationship between the angle of shearing resistance and the relative density is a group of parallel curves representing different grading, for each grading it is noticed that increasing the relative density leads to an increase in the angle of shearing resistance as a result of reduction in voids between particles. Comparing the curves for grading (S1, S2, S3, S4,), it is found that increasing the uniformity coefficient leads to increases in the angle of shearing resistance for the same relative density. Figure (7) shows that the relationship between the angle of shearing resistance and the uniformity coefficient. It is noticed that increasing the uniformity coefficient leads to an increase in the angle of shearing resistance due to reduction in voids. For a certain uniformity coefficient the angle of shearing resistance increases with the relative density. For submerged condition, the angle of shearing resistance decreases slightly, about 2 degrees, compared to dry condition at the same uniformity coefficient.

6.2 Compressibility of sand

The modulus of elasticity of sand is studied in terms of the void ratio, angle of shearing resistance and uniformity coefficient for different stress level and different relative densities. From figure (8), it is noticed that increasing the void ratio leads to a decrease in the modulus of elasticity due to increasing the compressibility of sand at large void ratios. The modulus of elasticity decreases in a linear relationship with vertical stress and with the relative density. It is also noticed that, for the same void ratio, the modulus of elasticity measured in the submerged condition is slightly less than its value corresponding to the dry condition. This is due to the water action as a lubricant between sand particles which decreases the friction slightly and increases compressibility. Comparison made with the results of Lambe (1969) shows that the modulus of elasticity for Saudi tested sand is higher. This is, as stated in section 6.1, due to particle shape, and probably mineralogy.

The relationship between the modulus of elasticity and the angle of shearing resistance for different stress levels and different relative density is shown in figure (9). It is noticed that the modulus of elasticity increases with the angle of shearing

resistance. As the shearing resistance is increased the resistance of sand to compressibility increases. The modulus of elasticity increases in a linear relationship with the angle of shearing resistance. The same relationships mentioned in the dry condition of the submerged soils for all sand samples. Figure (10) shows that increasing the relative density for the same vertical stress leads to an increase in the modulus of elasticity in a linear relationship. Comparing the charts for grading (S1, S2, S3, S4), it is clear that increasing the uniformity coefficient leads to an increase in the modulus of elasticity. This is for all the relative density and vertical stress due to decreasing the void between sand particles. For the same relative density the modulus of elasticity increases with the vertical stress due to the reduction of soil compressibility with applied stress. This is shown in figure (8).

The modulus of elasticity in the submerged condition is slightly less than the value corresponding to the dry condition for the same relative density and vertical stress. This is due to using the water action as a lubricant between sand particles which decreases the friction slightly and increasing the compressibility. From figure (10), it found that the relationship between the modulus of elasticity and vertical stress is a group of parallel lines representing different relative density, for each relative density, it is noticed that increasing the uniformity coefficient leads to an increase in the modulus of elasticity due to reduction in voids.

7. CONCLUSION

The main results can be summarized as follows:

For all sand samples, it has been found that increasing the void ratio or porosity leads to a decrease in the angle of shearing resistance for dry and submerged conditions. The angle of shearing resistance decreases slightly about 2 degrees compared to dry condition at the same uniformity coefficient and void ratio. The angle of shearing resistance increases with both relative density and the uniformity coefficient for all samples in dry and submerged conditions. The modulus of elasticity decreases as the void ratio increases in dry and submerged conditions.

The modulus of elasticity in the submerged condition is lower than the corresponding modulus in the dry condition for the same relative density and uniformity coefficient. The modulus of elasticity increases with the vertical stress or relative density and also leads to increasing the uniformity coefficient.

The relationship between the angle of shearing resistance and the modulus of elasticity is linear. Increasing the angle of shearing resistance leads to increasing the modulus of elasticity. A little effect of submergence on the relationship between angle of shearing resistance and modulus of elasticity has been noticed.

The obtained results are compared with the values of (ϕ) and the modulus of elasticity given by Lambe (1969) for different void ratios which show higher values of Saudi tested sand. This is due to particle shape and mineralogy.

8. REFERENCES

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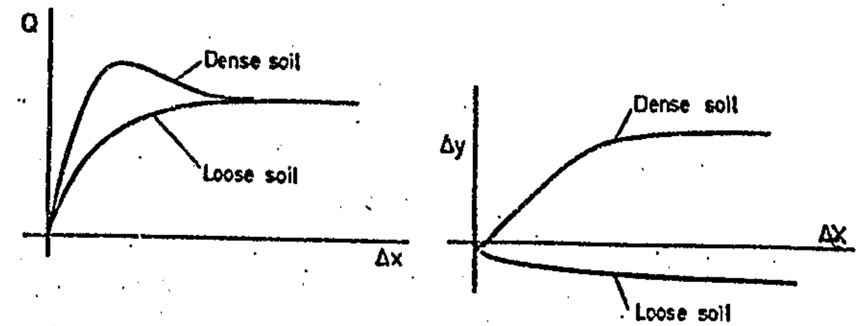


Fig(1) Results from Direct Shear Test (after Milligan & Houlsby, 1984)

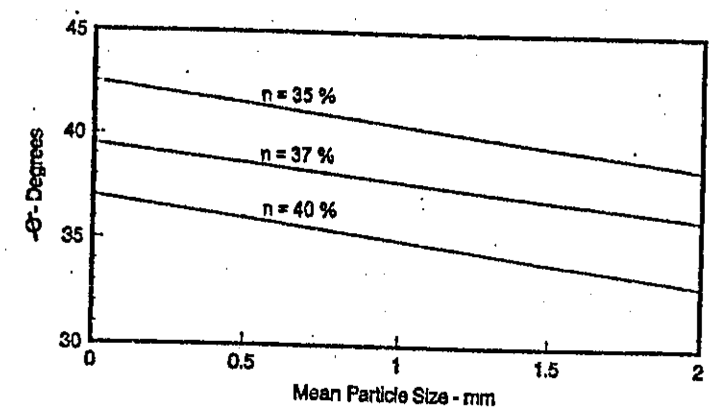
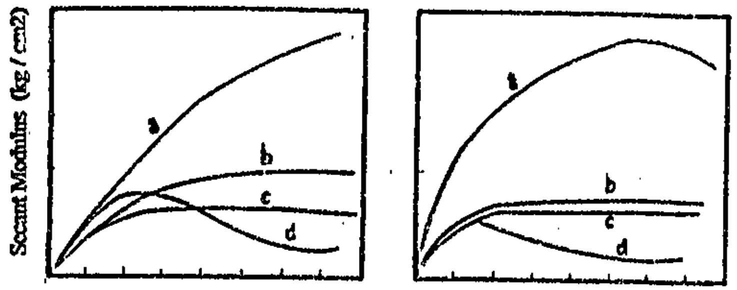


Fig. (2) Relationship Between Angle of Shearing Resistance and Particle Size (after Smith, 1981)



Vertical Stress (kg/cm2)
a : Minnesote sand
c : Wabash river sand

Vertical Stress (kg/cm2)
b : Sanymon river sand
d : Pensylvania sand

Fig. (3) Behaviour of Several Sands During One Dimensional Compression. (after KirkPatrick, 1965)

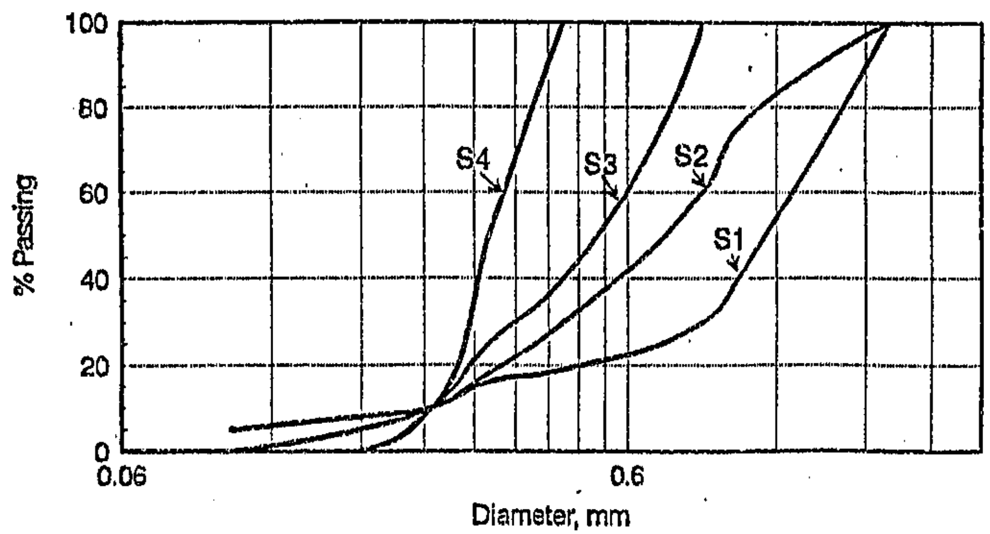


Fig. 4. Grain Size Curves

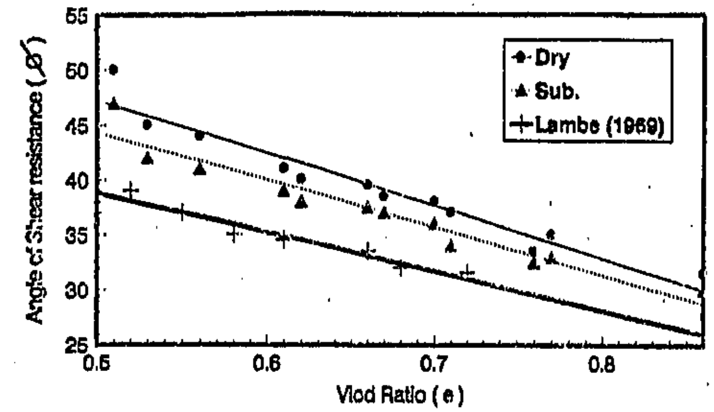


Fig. (5) Relationship Between The Angle of Shearing Resistance and The Void Ratio

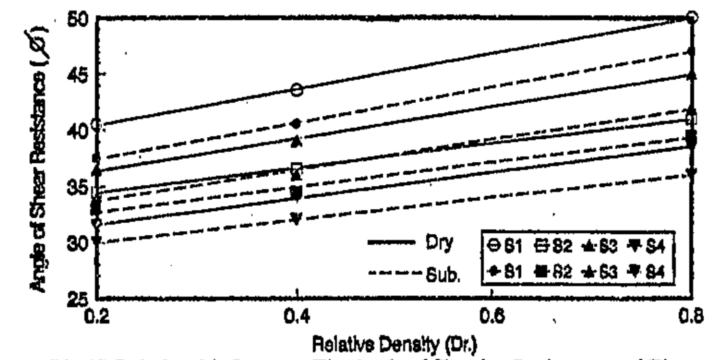


Fig (6) Relationship Between The Angle of Shearing Resistance and The Relative Denisty

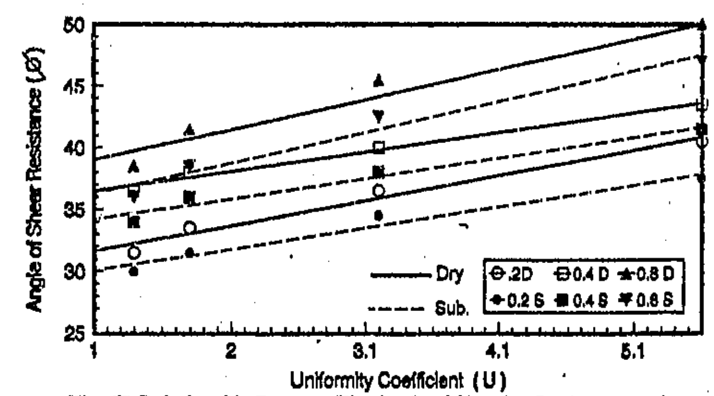


Fig. (7) Relationship Between The Angle of Shearing Resistance and Uniformity Coeffecient.

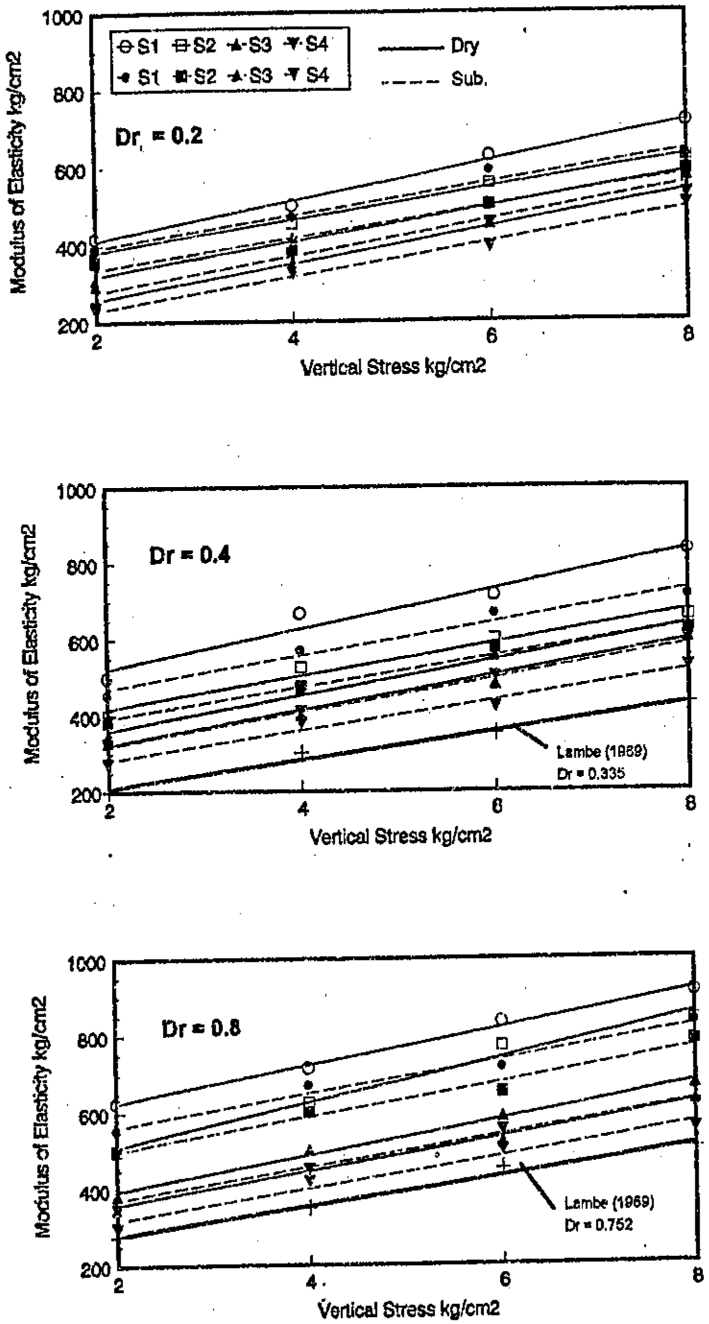


Fig. (8) Relationship Between The Modulus of Elasticity and Vertical Stress for Defferent Relative Denisty and for Dry and Submerged Conditions

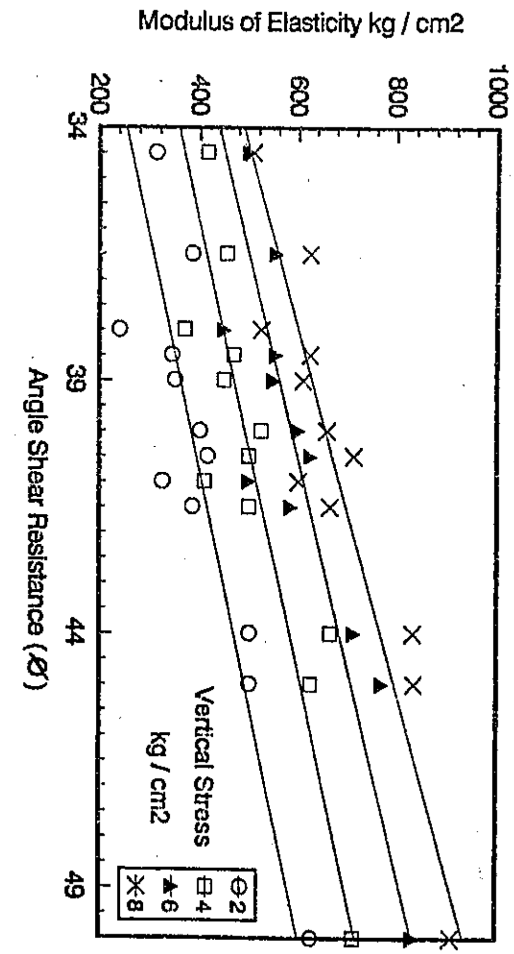


Fig. (9) Relationship Between Modulus of Elasticity and Angle of Shearing Resistance for Dry Condition

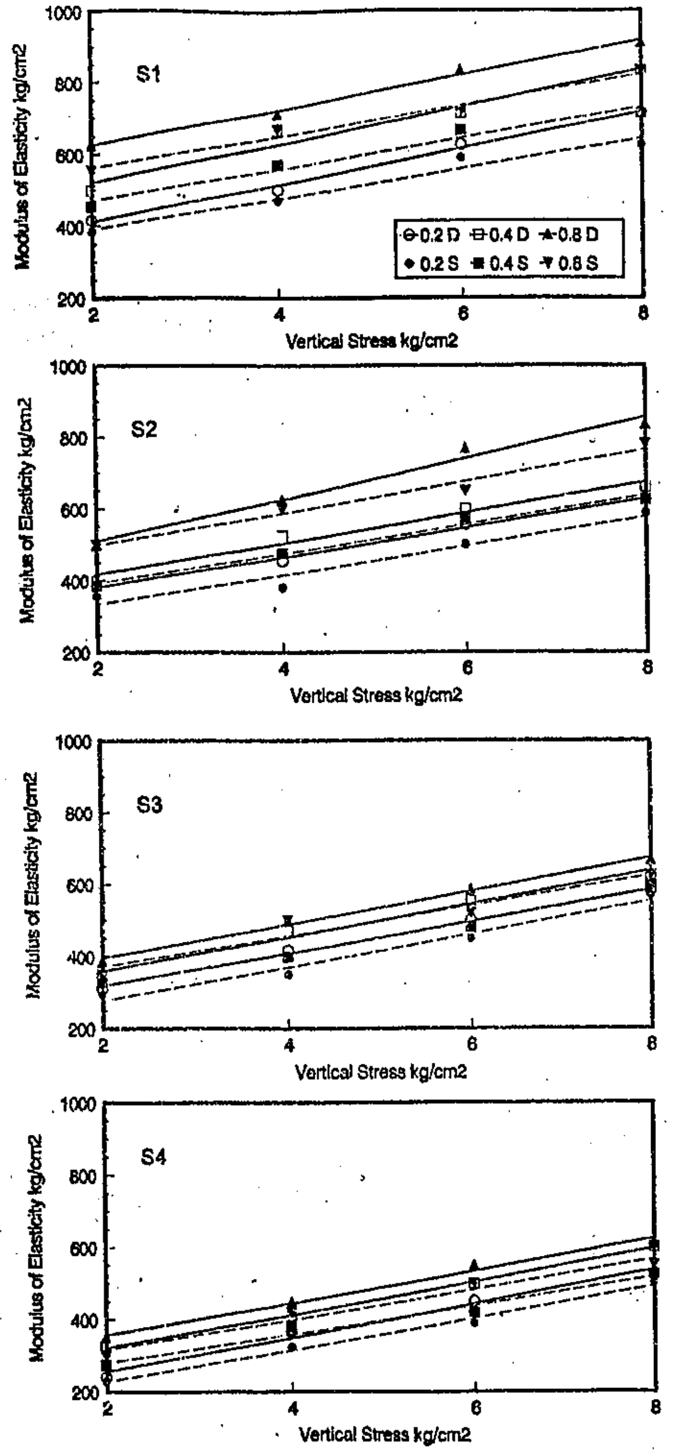


Fig. (10) Relationship Between Modulus of Elasticity and Vertical Stress for Defferent Relative Denisty