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Study on Strength Characteristics of Soil Reinforced by Used Polythene Fabric

by

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Introduction

One of the most significant recent deevelopments in improving the properties of soil is reinforcement using geofabric. The use of geofabric in soil proved to be economical, effective and easy to construct. The geofabric used extensively in civil engineering applications perform the functions of reinforcement, separation, filtration and drainage.

Review of Literature :

Koerner (1986) reports on the use of geosynthetics as a developing, exciting and rapidly growing field within Civil Engineering. He defines geosynthetics as all Synthetic materials used in getechnical engineering applications including geotextiles, geogrids, geocells, geomembrances and geocomposites.

Rao *et. al* (1989) report that the use of geosynthetics in Civil Engineering projects for ground improvement is becoming increasingly common the world over. At present there are numerous products available in international market and many in the Indian market too. The variety of these products makes it difficult for the engineer to choose a suitable material. A scientific approach to selection would be to determine the effective utility in terms of its response with soil i.e., behaviour of composite soil-geosynthetic mass. In addition to this there are several other considerations like durability, survivability of the products and economy.

Rao *et. al.* (1987) have conducted tests to evaluate the mechanical properties of textiles in the Indian context. They have evaluated three types of Indian make polypropylene geotextiles. Strength of the geotextiles was evaluated through tensile strength test, plunger-push-through test and cone drop test.

Krishnaswamy *et. al.* (1989) report on the study of evaluation of strength

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of the three types of Indian made geofabrics. The results indicated that there is not much difference in strength obtained by narrow strip tensile strength test and wide strip tensile strength test.

Talwar (1981) reports the attempt made to evaluate the shear parameters on poorly graded fine sand reinforced with geosynthetics. The lateral confining pressures have been varied over a moderately large range to induce failures of both the types. Based on the study he concluded that triaxial samples of sand reinforced with rings of aluminium foil and discs of aluminium sheet, behave like brittle material in rupture plane. The axial strains at failure increases as the strength of reinforcement increases. Horizontal reinforcement in the sample inturn is responsible for the enhanced friction angle in slippage or apparent cohesion in repute, which involves the increase in strength.

Rao *et. al* (1987) have reported the results of triaxial tests conducted on a fine uniform Yamuna sand reinforced with two types of Indian made woven geotextiles. HUSSMAN's Model developed for metalic reinforcement was verified. Based on their investigation it was concluded that

(*i*) The effect of placement of reinforcement is maximum at a confining pressure of 100 kN/m^2.

(*ii*) At higher confining pressures, the increase in deviator stress decreases : increase in deviator stress depends on tensile strength of reinforcements.

(*iii*) Deviator stress is increased by 15% when two discs of reinforcement were used.

(*iv*) Use of two discs are effective. At low confining pressures, reinforced sand registered an increase in the strength compared to unreinforced sand. At high confining pressures, ϕ decreases and '*c*' increases.

Natarajan *et. al.* (1987) report the study on a series of triaxial compression tests and unconfined compression tests on samples of clay reinforced with geotextile discs at various spacings in the soil specimens. Three types of geotextiles have been used in the investigations. Results of the study indicated the improvement in strength of soft clays due to presence of geotextiles. Improvement in strength depends on surface roughness of geotextiles, higher the roughness, higher the strength.

Subbarao *et. al.* (1987) investigated Ennore sand reinforced with indigenous polypropylene strips and subjected to traxial loading. They indentified mainly three types of failures. The study indicated that the inclusion of reinforcement of polypropylene, forms a new composite material characterised by increased friction angle or cohesion or both.

Gray *et. al.* (1986) report a series of triaxial tests on sand reinforced with fabric layer and stress-strain responses were studied. The results indicated an improvement in strength due to reinforcement, increased axial strain at failure and reduction of post peak loss in strength.

Rao *et. al.* (1989) investigated the triaxial behaviour of geotextile reinforced sand. Indian made woven and nonwoven geotextiles were used as reinforcements. The changes in stress-strain, volume changes, strength parameters and strengths have been investigated. The relationship between confining pressure and increase in confining pressures due to reinforcement was established for both woven and nonwoven geotextiles reinforcement. The established relationship between the ratio of confining pressure to the induced confining stress and confining pressure is a straight line. The relationship is of hyperbolic form as :

$$\frac{\sigma_3}{(\Delta\sigma_3)_i} = a + b\sigma_3$$

where

a and b = constants,

σ_3 = confining pressure,

$(\Delta\sigma_3)_i$ = induced confining pressure,

It is possible to predict the induced confining stress for any given confining pressure from the above equation.

The study indicated that the reinforcement induced confining stress was found to vary hyperbolically with the applied confining pressure for both types of reinforcements. Also the ratio of calculated and measured values of $(\Delta\sigma_3)$ was found to approach unity in general.

This paper attempts to show the potential use of woven polythene geofabric as soil reinforcement based on extensive laboratory tests. In this study geofabric obtained from old used polythene bags are used as reinforcing material to improve the soil with the following additional advantages :

(1) These are easily available as scrap material.

(2) They are of uniform thickness and have relatively constant properties.

(3) They possess acceptable value of water permeability.

(4) They are less susceptible to chemical decay and biodegradation.

(5) High tensile strength as compared to the soil.

(6) Flexibility for use in any form or shape.

Objectives and Scope of the Present Study:

The main objectives are :

(1) To study the feasibility of using the used polythene bag, a scrap material, as a reinforcing material in soils.

(2) To analyse the shear strength of the soil reinforced with this type of geofabric.

(3) To formulate a relatively simple theoretical model based on limiting equilibrium of forces to analyse the influence of the fabric and to identify the important test parameters and soil variables.

Experimental Investigations

Soil

In the present study tests were conducted on a locally available soil around Shimoga city. The physical and engineering properties were determined as per Bureau of Indian Standard Code of Practice. The test results are indicated in Table 1.

Geofabric

The physical and engineering properties of the geofabric from polythene bags are indicated in Table 2. The results indicated in this are the average of test results for the different used polythene woven fabrics from old bags selected at different locations. These are the representative samples. Hence there is no significant variation in their properties.

TABLE 1

Properties of Soil

1. In-situ density	17.7 kN/m^3
2. Field moisture content	8.0%
3. Specific gravity (34°C)	2.53
4. Maximum dry density	19 kN/m^3
5. Optimum moisture content (O.M.C)	12.8%
6. Coefficient of pereability, K	234 $\times$ 10^{-5} mm/s
7. Relative Density	82.5%
8. Soil classification as per I.S.	SM

TABLE 2

Properties of Geofabric

1. Material	Polythene
2. Specific gravity (34°C)	0.833
3. Weight	0.10378 N/m^2
4. Thickness	0.15 mm
5. Breaking Strength	
—Warp direction	920 N
—Weft direction	960 N
6. Elongation at Break	
—Warp direction	34.6%
—Weft direction	50.76%
7. Water permeability	3.78 $Lt/s/m^2$ at 100 mm water head
8. Maximum pore size	0.478 mm
9. Number of yarns/cm length	
—Warp direction	4 Nos.
—Weft direction	4 Nos.

Laboratory tests

Conventional triaxial compression tests were run on unreinforced and reinforced soil with several discs of reinforcement to examine the influence of different variables and to investigate the influence of fabric reinforcement in the soil.

More than 150 triaxial compression tests were conducted on unreinforced and reinforced samples of soils. All tests conducted in this study were unconsolidated undrained tests at various confining pressures.

Preparation of soil specimens

Soil passing through IS 425 micron sieve was mixed at plastic limit water content and cured for a period of 72 hrs. The specimens were compacted statically in a mould to get a constant density of 21.3 kN/m^3. Height to diameter ratio of the specimens was 2 : 1 (38 mm dia).

The specimen with reinforcement was prepared as follows. They are reinforced with 1, 2 and 3 nos. of discs. For a specimen reinforced with one disc, the soil was filled in two layers. Exactly half the weight of soil required for full specimen was placed in the mould and rammed to get exactly half the height of the specimen. One disc of reinforcement was placed on this layer and the soil required for the second layer is poured and compacted to the required height of the specimen. The specimens were regularly checked for constant density. Similarly the specimens with two and three reinforcement discs were prepared.

The triaxial tests were conducted at confining pressures of 100, 200 and 300 kN/m^2. The tests were performed at a constant rate of strain of 0.6 mm/min. The water content of the specimen was determined before and after testing.

The stress strain response of the soil is indicated in Figs. 1, 2 and 3. The Mohr's diagram is given in Fig. 4. The transformed stress-strain response is given in Figs. 5, 6 and 7. The measured and predicted value of the strength of the soil is indicated in Table 3. The variation of strength ratio with reinforcement is tabulated in Table 4.

Data analysis

The unconsolidated undrained Triaxial data is analysed for stress strain characteristics using Kondner's hyperbolic model. Kondner's expression for the triaxial stress-strain curve is in the form (Rao *et al.*, 1989).

$$(\sigma_1 - \sigma_3) = \frac{\epsilon}{(a+b\epsilon)} \tag{1}$$

where $(\sigma_1 - \sigma_3)$ = deviater stress,

ϵ = axial strain,

a and b = Kondner's constants,

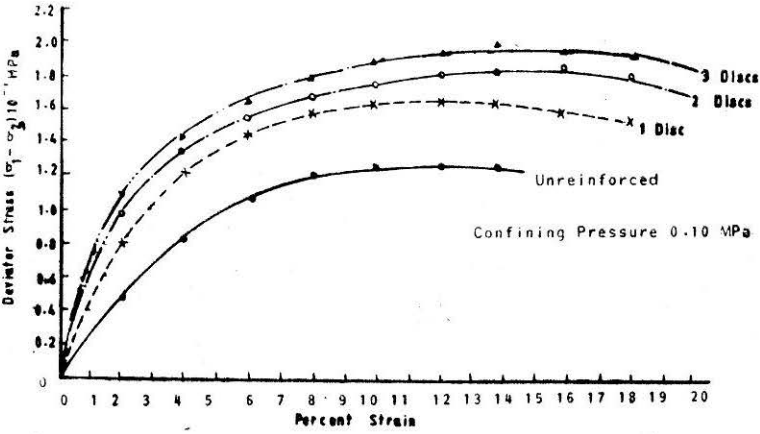


FIGURE 1 Deviator Stress Vs Percent Strain

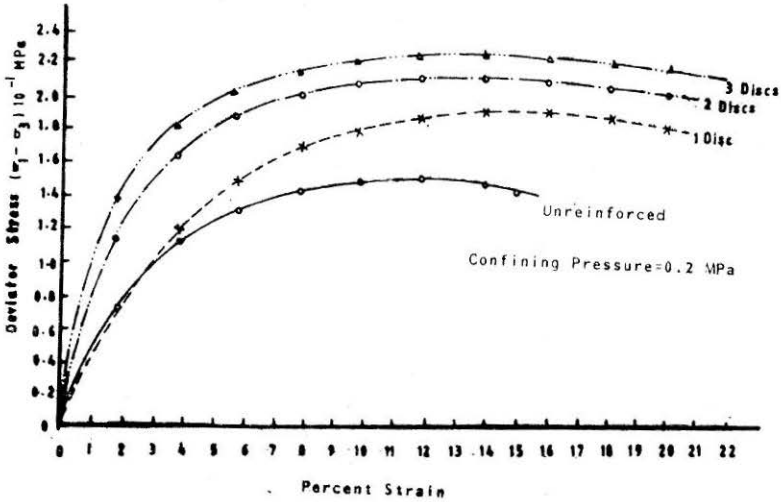


FIGURE 2 Deviator Stress Vs Percent Srtrain

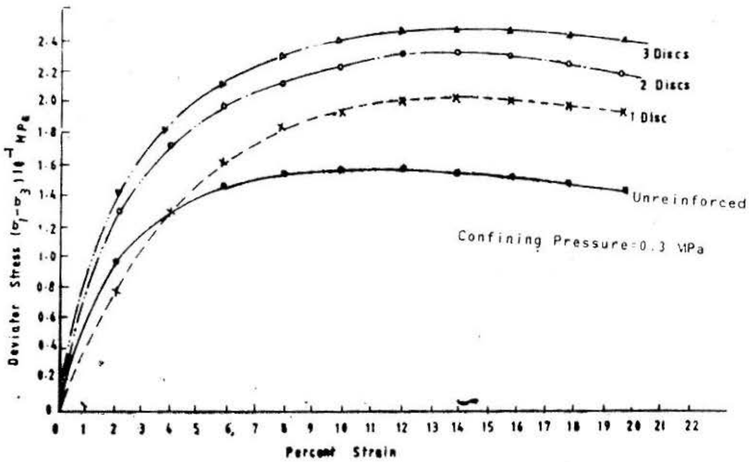


FIGURE 3 Deviator Stress Vs Percent Strain

'a' represents the intercept and 'b' the slope of the transformed plot. Constant 'a' is the reciprocal of the initial tangent modulus and constant 'b' is the stress difference at which the hyperbola becomes asymptotic at initial strain. Inverse of constant 'b' predicts the ultimate strength of specimen.

Evaluation of Kondners Constants

Kondner's equation may be rearranged as $\left(\frac{\epsilon}{(\sigma_1-\sigma_3)} = (a+b\epsilon)\right)$.

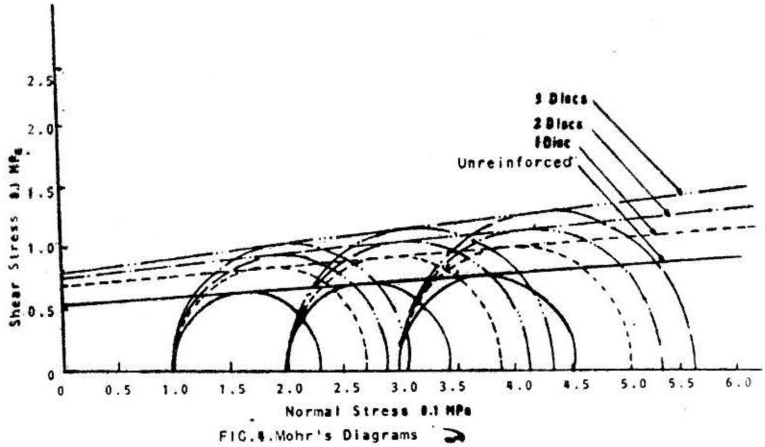


FIGURE 4 Mohr's Diagrams

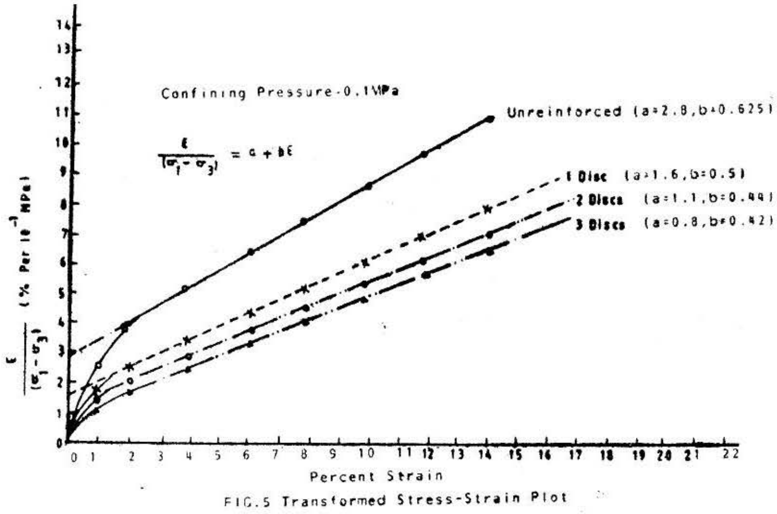


FIGURE 5 Transformed Stress-Strain Plot

Thus, when plotting $\frac{\epsilon}{(\sigma_1-\sigma_3)}$ Vs. ϵ, if the hyperbola describes the stress-strain curve accurately, all the experimental data should plot on a single straight line in the transformed plot with intercept '*a*' and slope '*b*'

The transformed stress-strain plots for the triaxial tests conducted are indicated in Figs. 5, 6 and 7. Kondner's constants were evaluated from the transformed stress-strain plot. The ultimate strength predicted from eqn. 1 is compared with maximum deviator stress obtained from test results and tabulated in Table 3.

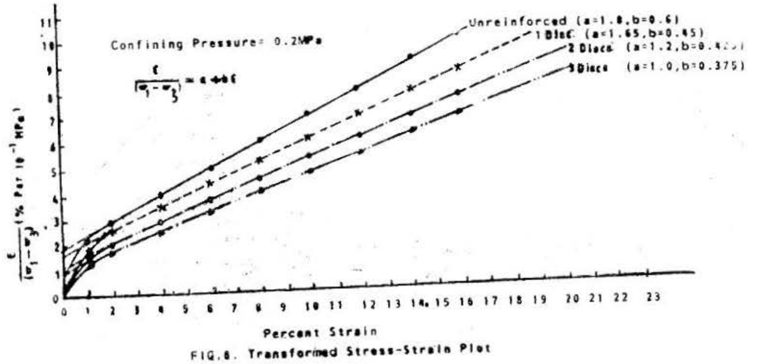


FIGURE 6 Transformed Stress-Strain Plot

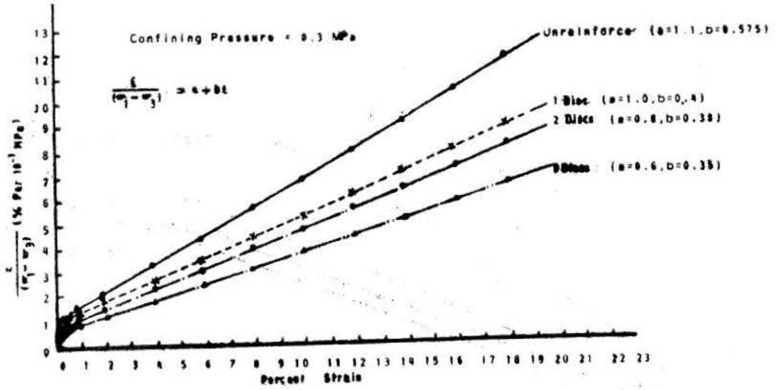


FIGURE 7 Transformed Stress-Strain Plot

Discussions on Test Results

The variation of deviator stress with respect to axial strain for unreinforced and reinforced samples are presented in Figs 1, 2 and 3. There is considerable increase in deviator stress in the reinforced samples. The increase in deviator stress is about 21 % when one disc is used, 29 % when two discs are used and about 35 % when turee discs are used. The deviator stress increases with increase in confining pressure. It is also observed from Figs. 1, 2 and 3 that the reinforced specimens can take greater strains. At the lower confining pressures, the increase in the percent strain with respect to reinforcement aspect ratio is more pronounced than at higher confining pressures. It is observed from Table 3 that the effect of reinforcement aspect ratio is more pronounced at a higher confining pressure of 300 kN/m^2.

TABLE 3

Measured and Predicted Strength of the Soil

Number of discs	Confining Pressure kN/m^2 (σ_3)	Failure strain in Percentage (ϵ_f)	Strength (σ_1—σ_3) KN/m^2 measured	predicted	Percentage Deviation of measured and predicted strength
0	100	12.10	1.32×10^2	1.60×10^2	17.50
1		12.50	1.68×10^2	2.00×10^2	16.00
2		15.20	1.88×10^2	2.2×10^2	17.18
3		15.30	2.10×10^2	2.38×10^2	11.76
0	200	11.80	1.60×10^2	1.67×10^2	4.19
1		13.50	1.92×10^2	2.22×10^2	13.51
2		13.90	2.18×10^2	2.35×10^2	7.23
3		14.60	2.30×10^2	2.6×10^2	13.53
0	300	11.80	1.65×10^2	1.74×10^2	5.17
1		13.80	2.18×10^2	2.50×10^2	12.80
2		13.90	2.38×10^2	2.63×10^2	9.50
3		14.40	2.57×10^2	2.86×10^2	10.14

TABLE 4

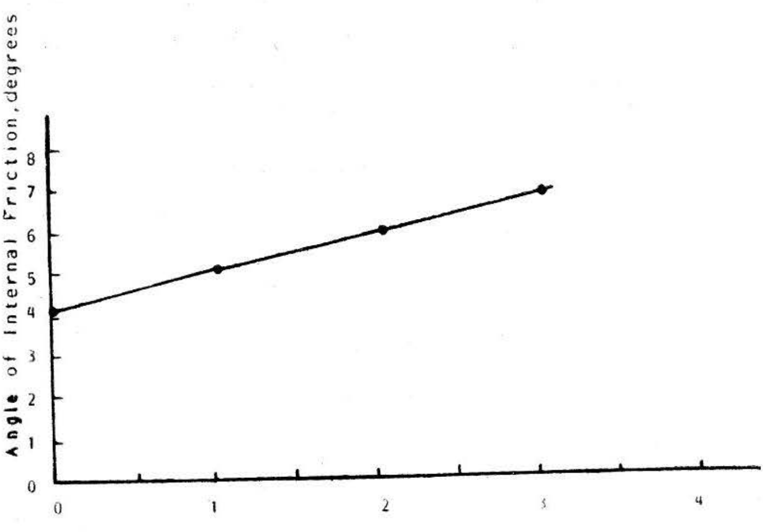
Variation of Strength Ratio with Reinforcement Aspect Ratio

Confining pressure (kN/m^2)	1 Disc	2 Discs	3 Discs
0	1.16	1.33	1.54
100	1.27	1.42	1.55
200	1.20	1.36	1.44
300	1.32	1.44	1.56

TABLE 5

Variation of Shear Parameters with Reinforcement Aspect Ratio

Sl. No.	Number of Discs	Cohesion (c) in kN/m^2	Angle of Internal Friction
1	0	55	4°
2	1	64	5°
3	2	73	6°
4	3	79	7°



Number of Reinforcement Discs

FIGURE 8 Variation of Angle of Internal Friction & Reinforcement Aspect Ratio

The variation of strength ratio with reinforcement aspect ratio is indicated in Table 4. It reveals that the strength ratio increased with reinforcement aspect ratio and also with confining pressure.

Shear parameters c and ϕ tabulated in Table 5 indicate higher shear strength with reinforcement aspect ratio. The variation of cohesion and the angle of internal friction with reinforcement aspect ratio is plotted in Fig. 4. It is clearly observed that in all the specimens reinforced with geofabric, the failure is by bulging rather than by the formation of definite failure plane. Also there is a good correlation between cohesion, angle of internal friction and reinforcement aspect ratio. The predicted strength based on Kondner's constitutive relationship is comparable with the measured strength and is within 17% deviation for all samples. The transformed

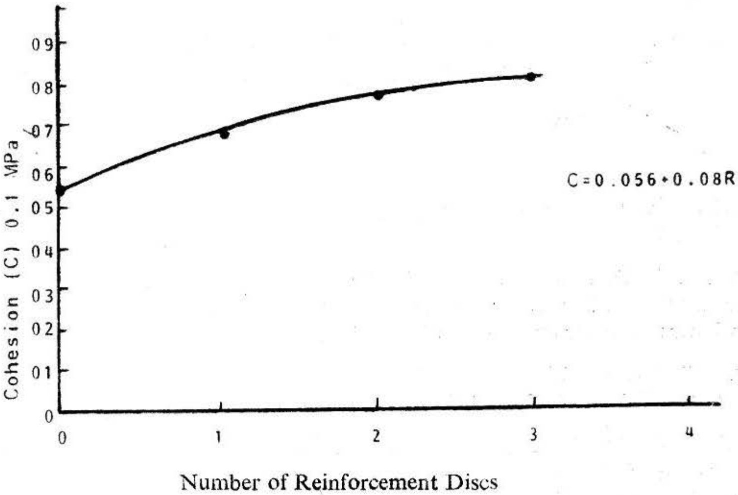


FIGURE 9 Variation of Cohesion & Reinforcement Aspect Ratio

plot of deviator stress and strain are shown in Figs. 5, 6 and 7. The hyperbolic concept of Kondner offer the advantage, that it's two constants are related to two important soil properties—viz. the initial tangent modulus and the compressive strength.

Full mobilisation of shear between the soil and the reinforcement is not realised when the reinforcement aspect ratio is increased. This may be due to the fact that the addition of reinforcement enables the specimen to take greater strains.

Conclusions

From the experimental study, the following conclusions are drawn, which are applicable to the materials used and the test conditions adopted.

1. Reinforced soil generally takes greater percentage of strain at failure.
2. There is significant increase in the value of cohesion with increase in reinforcement aspect ratio.
3. The angle of internal friction increases with decreasing reinforcement spacings.
4. Large strains would be required to reach peak shear resistance in case of soil reinforced with more number of reinforcement.
5. Kondner's hyperbolic relationship is found valid for all specimens, reinforced and unreinforced.
6. Good correlation exists between the cohesion, angle of internal friction and the reinforcement aspect ratio.

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