LABORATORY PULLOUT TESTS ON THE WIRE MAT REINFORCEMENTS WITH WEATHERED CLAY AS BACKFILL MATERIAL

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ABSTRACT

The study of pullout mechanism was carried out on full scale pullout apparatus. The aim of this study is to identify the mechanism of pullout resistance of a reinforced weathered clay using welded wire ½" and ¼" diameter steel mesh. The results of the study showed the pullout force-displacement curves generally have a yield point at a displacement ranging from 4 - 6 mm, the pullout resistance increase with the diameter of wire. By comparing the test results using backfill material at different water content, it was found that weathered clay backfill material is more effective compacted at dry side than those of wet side and optimum moisture content.

1. INTRODUCTION

Reinforced earth is a soil improvement technique proposed by Vidal (1969) using strip metal reinforcements. The main component of a reinforced soil structures are fill material and reinforcing elements. Granular soils are mostly used as backfill materials. Recently, welded wire mesh (as a grid reinforcements) has been used as soil improvement in the construction of reinforced soil embankment.

Chang (1977) has observed that the grid or mesh reinforcement is more effective than strip reinforcement. The grid reinforcement may achieve a peak pullout of about six times than the strip reinforcement (Bishop & Anderson, 1979).

Recently, researchers have tried to study the pullout resistance for many type of grid reinforcement materials, in the laboratory model tests as well as in the field tests. Only a few of them deals with cohesive soils as backfill material. Since many part in the world like Indonesia, where vast area are covered with cohesive soil, the need for research on the use of cohesive back fill material is likely required.

2. PURPOSE AND SCOPE OF STUDY

The purpose of this study is to identify the mechanism of pullout resistance of a reinforced weathered clay using welded wire ½" and ¼" diameter steel mesh with mesh size 6" x 9" in the laboratory. To fulfil this objective, eighteen welded wire mats were pulled in a full scale testing apparatus in the laboratory as well as in the field.

3. THEORETICAL BACKGROUND

3.1. Pullout Resistance of Geogrid Reinforcements

Peterson and Anderson (1980) had proposed that the pullout resistance of mesh reinforcement consist of frictional resistance of longitudinal bars and bearing capacity of transverse members. For geogrids reinforcement with cohesive frictional or poor quality fill, there is an adhesion rather than friction. The total pullout resistance of the grid reinforcement can be expressed as:

$$F_t = F_f + F_p \tag{1}$$

where:

F_p = passive resistance

F_f = frictional resistance.

Peterson and Anderson (1980) has also suggested an equation of pullout resistance which is based on the Terzaghi - Buisman (1947) formula:

$$Q_{ult} = B\, cN_c + 0.5\, \gamma\, d\, B\, N_\gamma + B\, \sigma_v\, N_q \tag{2}$$

where:

B = width of footing
c = cohesion
γ = effective unit weight of soil
σ_v = effective overburden
N_c, N_q and N_γ = bearing capacity factors
d = diameter of reinforcement

Equation (1) can be arranged in term of F_p (pullout resistance) provided by the transverse members alone as:

$$F_p/nwd = cN_c + 0.5\, \sigma_v\, dN_\gamma + \sigma_v\, N_q \tag{3a}$$

where:

w = width of the reinforcement
n = number of transverse wires

$F_p/(nwd)$ is the bearing passive resistance per unit length of one transverse wire. Since the value of d = B is small, the second term can be neglected and the equation (3) becomes:

$$F_p/nwd = cN_c + \sigma_v\, N_q \tag{3b}$$

3.2. Punching shear Failure

This failure mechanism is proposed by Jewell et al. (1984), which is based on the failure mechanism of low bearing pressure on deep footings. In this case, bearing capacity factor is expressed by:

$$N_q = e^{(90 + \phi)\, \tan(45+\phi/2)} \tan (45^\circ + \phi/2) \qquad (4)$$

where ϕ is the angle of internal friction of soil.

3.3 Adhesion of Longitudinal Bars

The total adhesion resistance of longitudinal bar (F_f) for cohesive frictional or frictional soil can be determined by expression (Jones, 1985):

$$F_f = \mu\, \pi d\sigma_v \qquad (5)$$

where:

   μ = adhesion factor
   σ_v = overburden pressure at level of reinforcement
   d = diameter of longitudinal member.

4.   EXPERIMENTAL INVESTIGATION

4.1 Compaction Tests

The Standard Proctor compaction tests were carried out to determine the optimum moisture content and the maximum dry density of weathered clay backfill.

4.2 Direct Shear Tests

The electrical operating direct shear machine with large shear box (15.2 cm x 15.2 cm was employed. The shear force was measured by means of a loading ring. Both horizontal and vertical displacements were observed through dial gages. The strain controlled tests were carried out at 1 mm/min rate. In these tests, the sample was reinforced and unreinforced. Testing with unreinforced sample was used to determine the undrained shear strength of soil, while testing with reinforced sample was used to determine the adhesion factor of reinforced soil.

4.3 Pullout Tests

Laboratory pullout tests are conducted using a modern pullout test apparatus with an automatic data acquisition system and servo controlled pullout test force mechanism. Schematic view of the apparatus are shown in Fig.1. The pullout cell has an inside dimension of 50" x 30" x 20" (Length x Width x Height). The normal loads are applied by inflating an air bag fitted in the pullout box, over the flexible metal plate (1/4" thick), which is placed direction top of compacted soil. A constant pressure is maintained throughout the tests using a regulator. The pullout force is provided by operating a hydraulic jack against the supporting frame which was fixed 40" in front of the pullout box. The reinforcing mat is attached to the ram using a well designed clamping mechanism such that the retraction on the ram provides the necessary pullout force. The horizontal displacement of the reinforcement is monitored using the linear variable differential transformer (LVDT). The strain gages were used to evaluate the in soil strain

response and stress transfer mechanism of the reinforcement. The pullout tests were performed by constant strain condition.

5.   PRESENTATION OF RESULT AND DISCUSSION

5.1 Compaction tests

Results of compaction test using Standard Proctor for weathered clay backfill material is shown in Fig. 2. The optimum moisture content (w_{opt}) of 22.3 % and maximum dray density (γ_d) of 1.545 t/m^3 were obtained from moisture content - dry density curves.

5.2 Direct Shear Tests

Direct shear tests without reinforcement yielded undrained shear strength of weathered clay backfill, c_u = 9.8 t/m^2 and the angle of internal friction ϕ = 29.15°. The results of direct shear tests with welded wire bar inclusions for both with transverse and longitudinal bar are shown in Fig.3. The undrained shear strength c_u = = 6.6 t/m^2 and the angle of internal friction ϕ = 35.1° were obtained from direct shear tests with both transverse and longitudinal bars, while c_u = 5,8 t/m^2 and ϕ = 33.1° were obtained from direct shear tests with longitudinal bar only. Observation of these two tests after shearing indicated that there was an evidence of slippage between reinforcements and soil.

Comparison the cohesion intercept and the angle of internal friction of weathered clay alone (Fig. 3), it was found that the inclusion of reinforcement resulting in reduction of cohesion intercept, but the angle of internal friction increased. The higher angle of internal friction was found in the direct shear tests with both transverse and longitudinal bars.

Results of these tests were used to determine the adhesion factor (μ) between reinforcement and soil as shown in Fig. 4. In these results, μ_t is adhesion factor between soil and reinforcement with both longitudinal and transverse bars, and μ_{wt} is adhesion factor between soil and longitudinal bar only. The adhesion factor (μ) for the wire mats with mesh size 6" x 9" was taken from the combination between adhesion factor with and without transverse bar by considering ratio of its area (i.e., $\mu = 0,33(2\mu_t + \mu_{wt})$).

5.3 Pullout Tests

The detail of wire mats used is shown in Fig. 5. The backfill material was compacted at 95% Standard Proctor at dry side and wet side of optimum, and 100% Standard Proctor at optimum moisture content. In these tests, several strain gages were damage due to the lack of necessary shield against vibrating impact forces from vibratory rammer and excessive amount of strain induced during testing.

Plot of the pullout force against displacement for both welded wire ¼" diameter is shown in Fig. 6. This result indicated as follows:

1.   The pullout force - displacement curves generally have a yield point at a displacement ranging from 4 - 6 mm.

2. After reaching a yield point, increasing displacement does not give significant increase in pullout force.

5.4 Effect of Wire Diameter to the Maximum Pullout Force

To determine the relationship between the pullout force and the diameter of wires, plots were made to shows the pullout force per unit width (F_p/w) against overburden pressure or normal pressure for constant diameter of wire mats (Fig. 7). The pullout resistance in this case is the resistance due only to transverse wires does not include the frictional resistance of longitudinal wires. From Fig. 7, it can be seen that when the wire diameter increased, the pullout resistance is also increased. This because increasing diameter, the failure plane around the wire increase in total length. Thus causing more utilisation of internal friction of the soil.

In order to compare between observed and predicted pullout resistance using the equation suggested by Peterson and Anderson (1980), the normalised passive bearing resistance was plotted together in Fig.8 for dry side, and Fig. 9 for wet side conditions. In these figures, F_p/nwd represents passive resistance per unit area of the transverse bar normal to the direction of pullout force. It was obvious that almost in all cases, the value of F_p/nwd definitely increased with increasing in normal pressure. It can be seen that weathered clay backfill is more effective compacted at dry side than those of wet side and optimum moisture side. The test results shows that the ¼" diameter bar gives a higher value of unit passive resistance (F_p/nwd) than ½" diameter bars. This phenomenon is caused by the lower strain occurred in the larger diameter (1/2") and thus the passive bearing resistance has not fully mobilised. Previous researchers (Chang et al., 1977; Hannon & Forsyth, 1978; Cisneros, 1989) have also reported that ¼" diameter welded wire bars gives higher unit passive resistance than ½" diameter. The regression line connecting the maximum pullout resistance is not continuous, since at lower normal stress, the soil tends to dilate. This effect of dilation is similar as those on dense granular soil (since the behaviour of compacted clay at dry side subjected to shear is the same behaviour as granular soil). From Fig.8 and Fig.9, it can be seen that in dry side condition, the observed pullout resistance is lower than predicted, while at wet side observed values were closer, but it still higher than those predicted by Jewell et al. (1984). This due to Jewell et al. prediction considers punching shear failure.

6. CONCLUSIONS

1. Results of direct shear tests indicated that inclusion of reinforcement in the soil resulting in reduction of cohesion intercept, but the angle of internal friction increased. The higher angle of internal friction was found in the direct shear test with both transverse and longitudinal bars.

2. The pullout resistance increases with the diameter of wire. This because increasing diameter, the failure plane arround the wire increase in total length, and thus causing more utilisation of internal friction of soil.

3. Laboratory pullout resistance at dry side of optimum is much higher than those optimum and wet side of optimum. Pullout resistance is generally increased with

overburden. Diameter of ¼" gives effective bearing resistance higher than those ½" diameter.

7. REFERENCES

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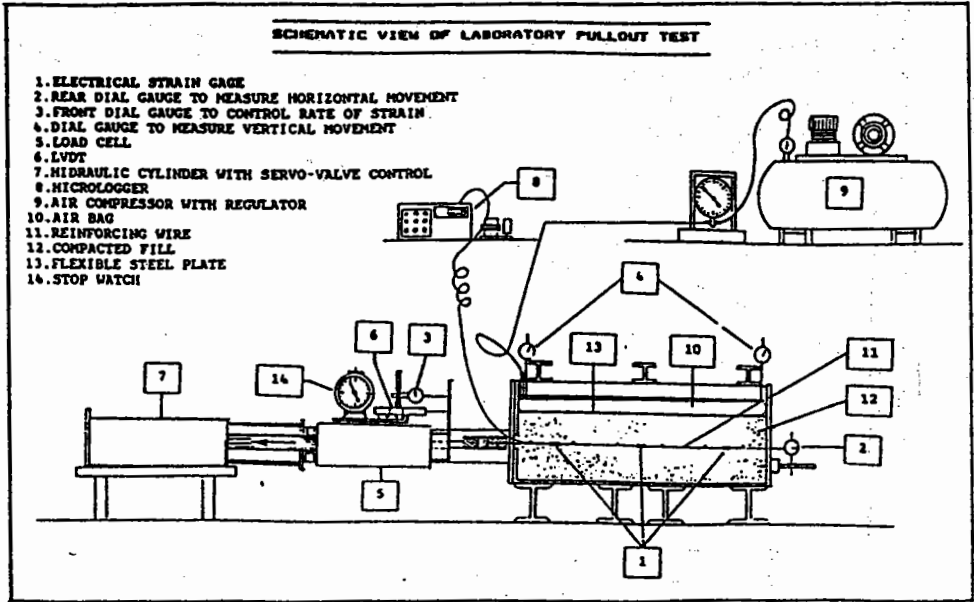
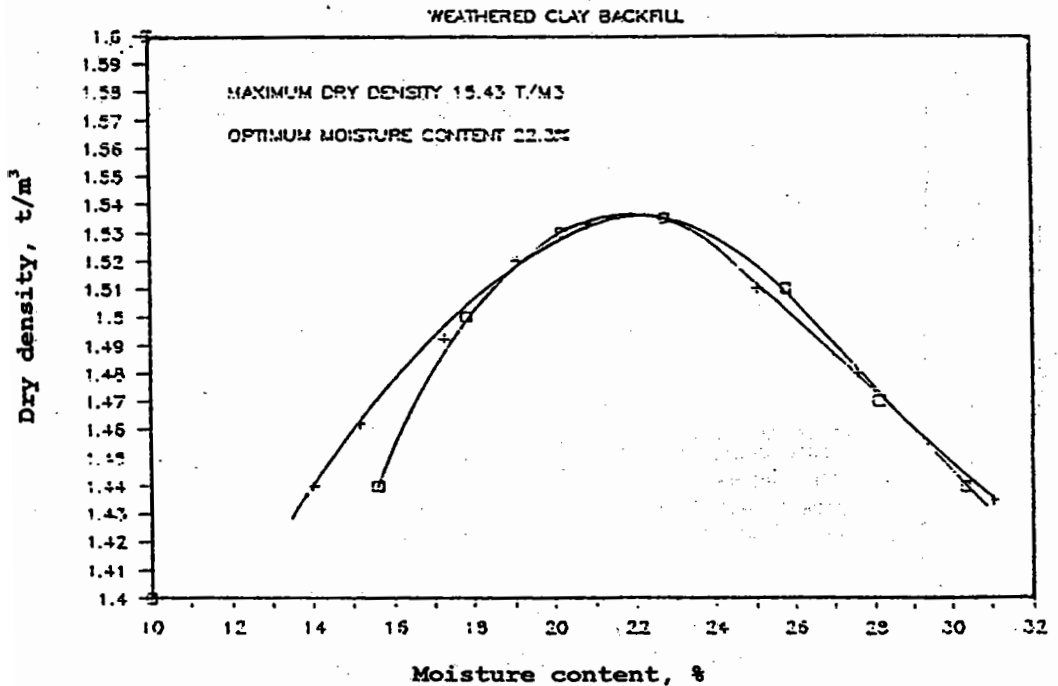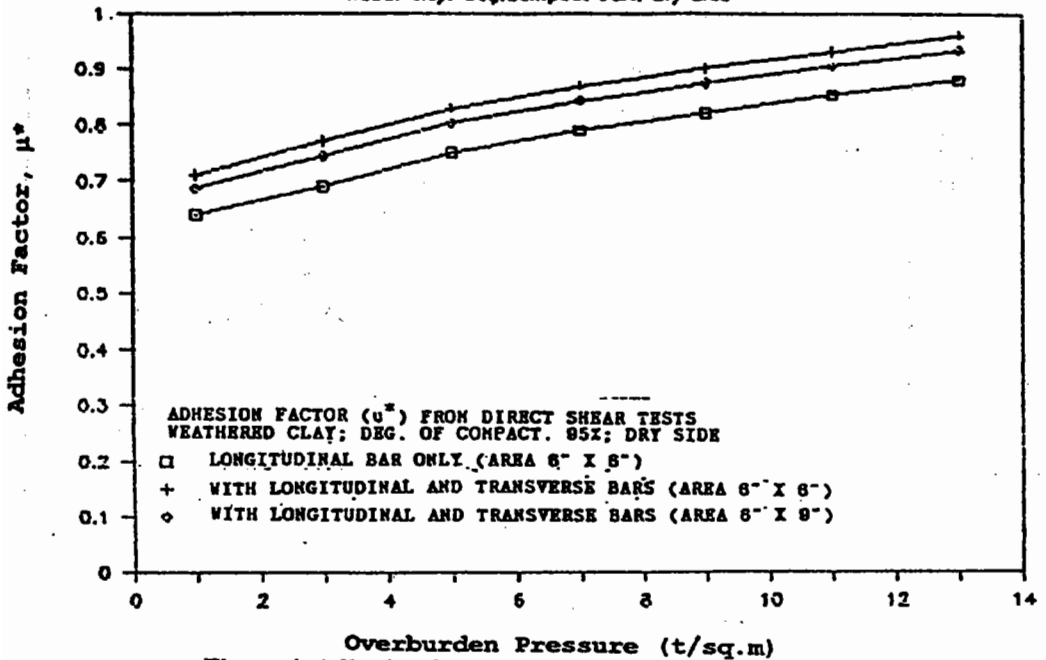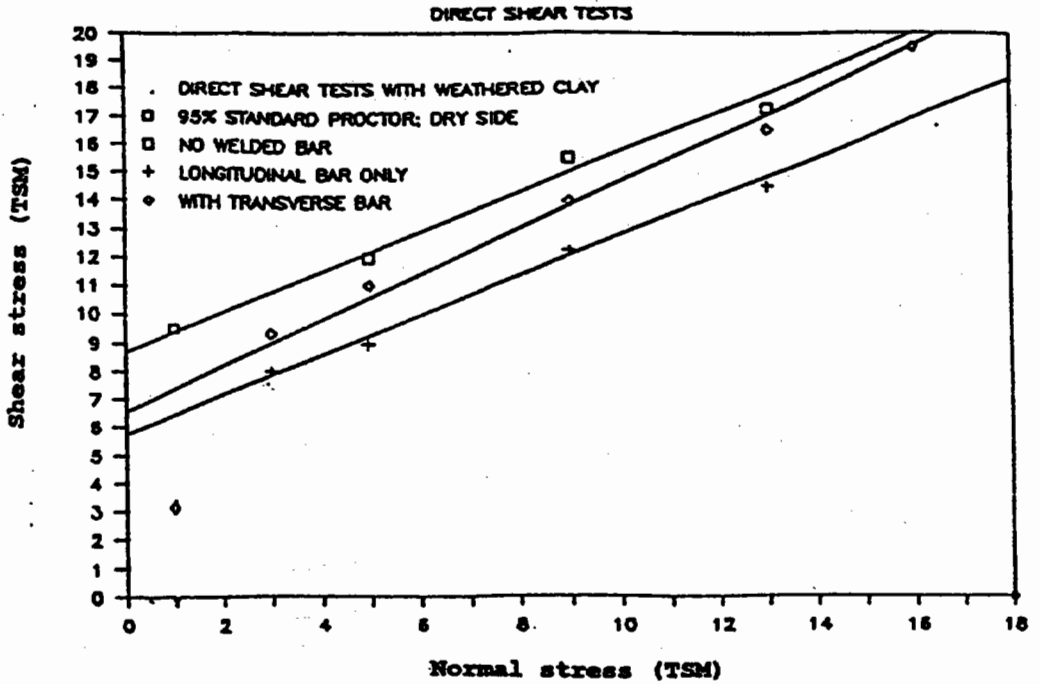**Figure 1. Schematic view of laboratory pullout test**

Figure 2. Results of Standard Proctor compaction tests for weathered clay backfill.

DIRECT SHEAR TESTS

Figure 3. Comparison of the results of direct shear tests.

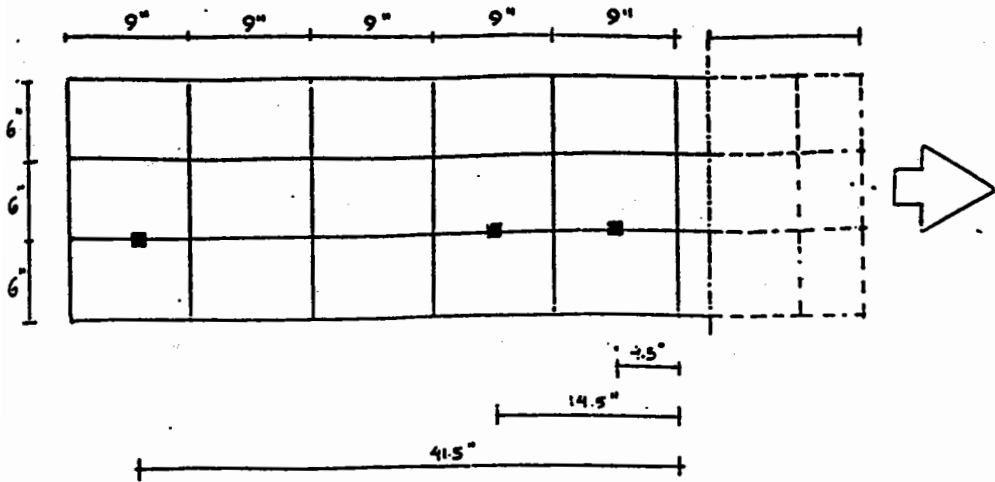**Figure 4. Adhesion factor vs. Overburden pressure for
welded wire mat with weathered clay backfill**

Figure 5. Detail of wire mats used for laboratory pullout tests
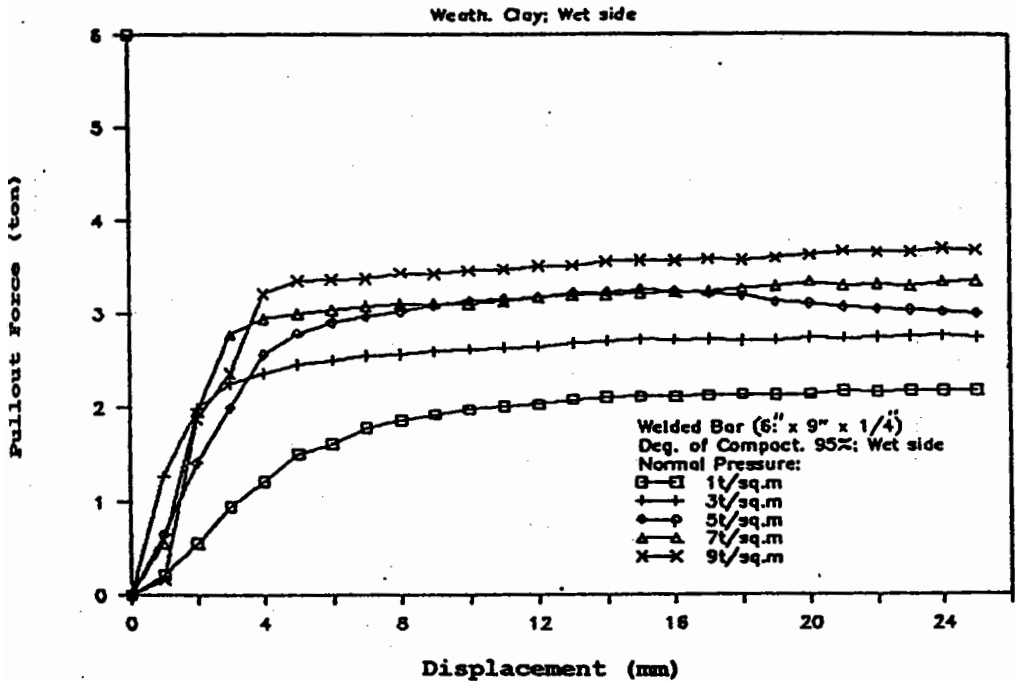
■ instrumentation points

**Figure 6. Pullout force vs. Displacement welded wire bar (6" x 9" x 1 / 4"),
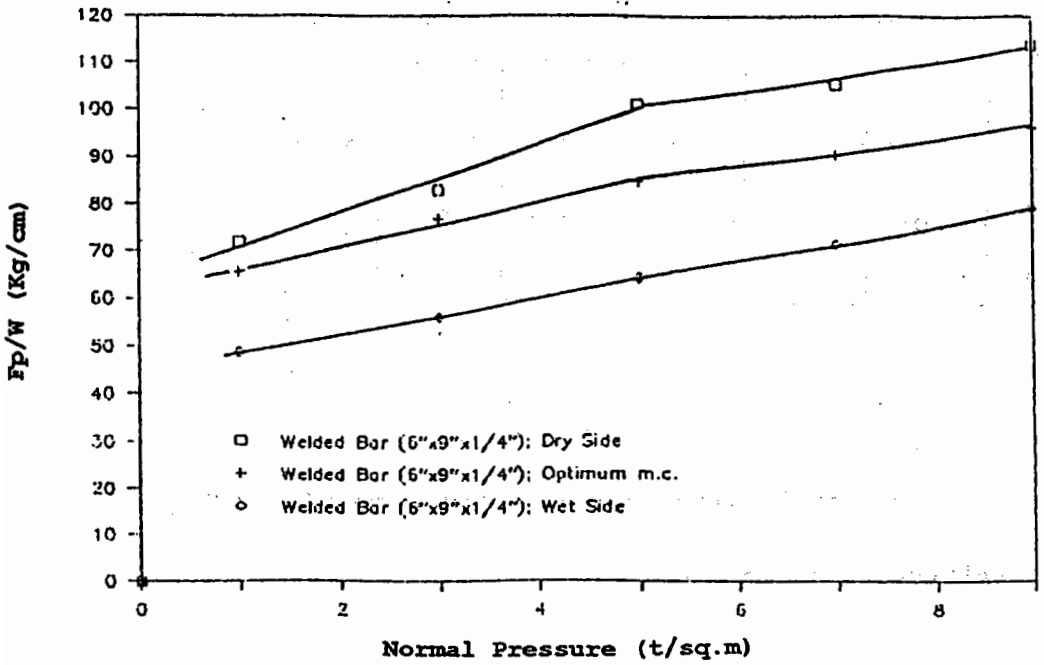compacted at 95% standard proctor, wet side of optimum**

Figure 7. Plot of F_p/w against overburden pressure for welded bar (6" x 9" x ¼")
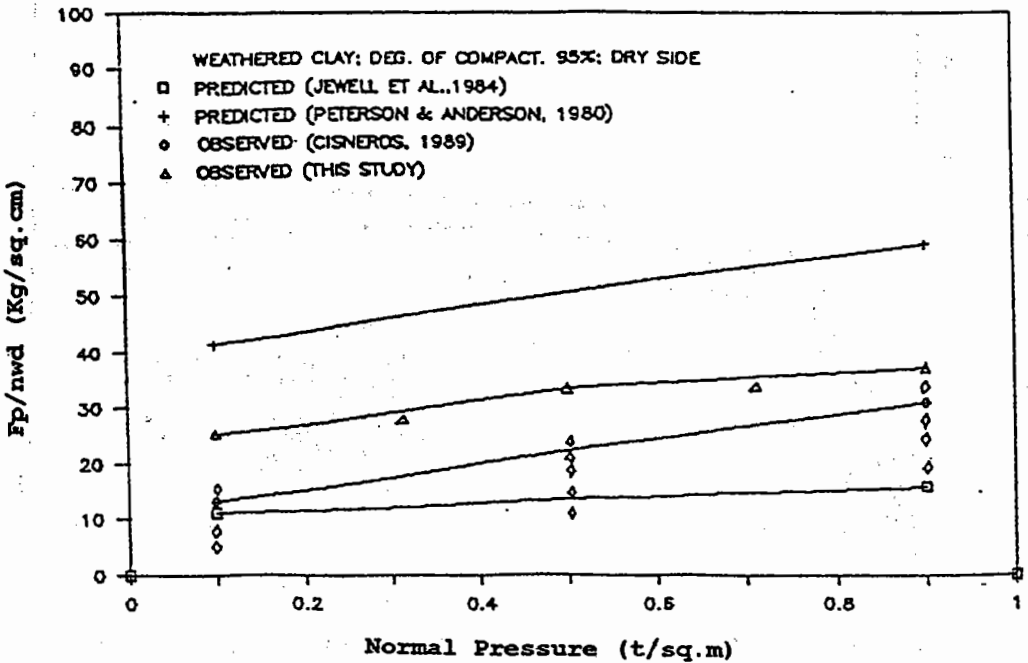

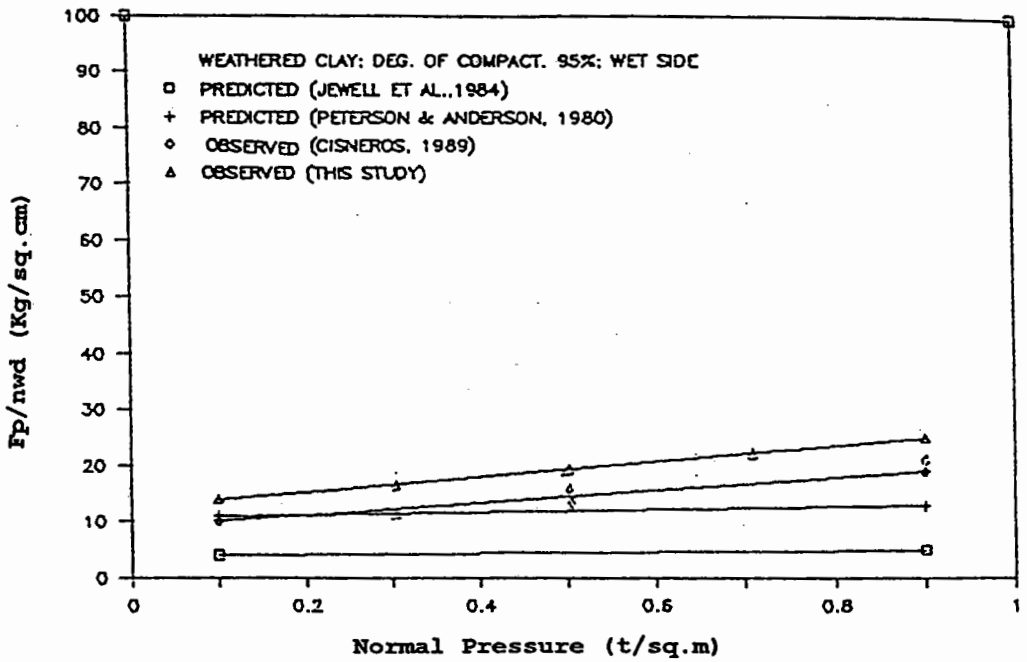Figure 8. Comparison of F_p/nwd vs. overburden pressure (Dry side of optimum)

Figure 9. Comparison of F_p/nwd vs. overburden pressure (Wet side of optimum)