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Model Test of a Rail-Ballast-Fabric-Soil System

Essai d'un modèle rail-ballast-textile-sol

ABSTRACT

The paper presents the results of a laboratory model tests to study the reinforcing functions of a geotextile in a rail-ballast-fabric-soil system. The geotechnical fabric (geotextile) caused the entire system to behave as a relatively elastic foundation, and therefore the response to loading can be predicted. It was also found that the reinforcing effect of the geotextile causes reduced deflections and strains within the whole system. Such laboratory model tests can serve as a steping stone for evaluation of input parameter for a numerical analysis scheme.

Ce présent article présente des essais modèles de laboratoire ā l'etude du rôle de renforcement d'un géotextile dans un systēme de rail-ballast-gēotextile-sol. Le gēotextile donne ā l'ensemble du systēme un comportement comparable ā celui d'un fondement relativement élastique. Donc, la réponse au chargement puet ētre estimée. Aussi, il a été observé que l'effet de renforcement du géotextile créait des flexions et deformation réduites dans l'ensemble du systeme. Tels essais peuvent servir comme le fondement d'urve évaluation des paramētres d'entrēe d'un algorithme d'analyse numērique.

INTRODUCTION

Model testing under controlled condition has been a forceful tool for studying mechanism in geotechnical engineering. This paper presents the results of a study to evaluate the performance of a selected geotextile in a rail-ballast-fabric-soil system under controlled laboratory model testing. The model test to be presented can be used as a qualitative basis to define the so-called input parameters for numerical analysis of the system using available models. The major objective of this study was to evaluate the reinforcing function of a selected geotextile. The investigation included the model testing of the system and also laboratory testing for evaluation of material characteristics.

DESCRIPTION OF MODEL TEST

The model consisted of:

a. A light crane rail with five wood ties.
b. A subgrade with known properties.
c. A selected geotechnical fabric.
d. A container tank for the soil and ballast; and for conducting the experiment.
e. A loading frame and equipment.

Rail and Ties. A.S.C.E. light 178 N (40 lb) crane rail 241 cm (95 in.) long with five oak wood ties 94 cm (37 in.) long, 5 cm (2 in.) wide and 4.57 cm (1.8 in.) thick, was used (Fig. 1). The ties were attached to the botton of rail by screws on both sides of the rail with steel tie plates (Fig. 2).

Subgrade. The soil used for subgrade consisted of 50% of Kaolin clay, 45% of Ottawa sand, 5% of Bentonite clay and 18.5% of water (by weight). The soil can be classified as a sandy clay with a specific gravity of 2.67, liquid limit of 44 and Plasticity Index of 22. The standard compaction test data provided an optimum moisture content of 16% and maximum dry density of 17.3 kN/m^3 (110 pcf). The soil used for the tests had a water content of 18.5%; slightly over the optimum. The ballast selected was from AREA No 4 of AAR Track Laboratory and consisted of low grade limestone. The maximum dry density of the ballast was 20 kN/m^3 (128 pcf). The grain size distribution for soil and ballast is shown in Figure 3.

Geotextile. AMOCO non-woven fabric STYLE EPRH-336 was used for this test.

Container. A steel tank 241 cm (95 in) long, 94 cm (37 in) wide and 105 cm (41.5 in) deep was used.

A soil mixer and a compactor was used during the preparation of subgrade. The soil was deposited in the tank and compacted in 10 cm (4 in) thick layers to a total thickness of 76 cm (30 in). About 10.67 cm (4.2 in) of ballast was then placed on top of the clay and then levelled. The soil and tie were placed on the ballast, and in the area where there were no ties additional ballast was placed to bring the total thickness to 15.25 cm (6 in). For the second test where the geotextile was used, the fabric was installed prior to placing the ballast. The fabric was placed with an initial tension by hanging a weight at the ends.

Loading Frame and Equipment. The loading frame (Fig. 4) was designed to apply a moving vertical load up to 45 kN (10,000 lbs) maximum. The moving load consisted of a single wheel 15.25 cm (6 in) dia and 9.62 cm (3 in) thick, was attached to hydraulic cylinder and electrical system (Fig. 5). The apparatus included a 1 HP electric three way motor, reversing control system, two limit switch, stainless chain and sprockets. The motor gave the power for the wheel to move at a constant speed of 25 secs. per trip, after touching the limit switch, the rotation of the motor reversed automatically and caused the wheel to move back to touch the other limit switch and vise versa to make it move back and forth.

Measuring Equipment. The data measuring equipment in the test included embedded soil stress and strain gages, steel and fabric foil strain gages and mechanical deflection gages. The soil stress gages were piezo-resistive gages. The soil strain gage consist of a pair of sensors 2.54 cm (1 in) in diameter. The average distance between the two sensors was about 2.54 cm (1 in). The soil stress and strain gages were placed in the soil at a depth of 9 cm (3.5 in). Prior to placing in soil standard calibration procedure was utilized. Figure 6 provides the plan view of the location of soil stress and strain gages.

A strain indicator unit were used to measure the strains of foil gages fixed at various locations on the rail. Six foil gages were fixed on the flanges of the rail to measure the bending of the rail (Fig. 6). Two foil gages were placed on each side of steel tank to measure any longitudinal or transverse deflection of the tank. Six foil gages were also fixed on the fabric to measure its expansion, however, the gages were damaged by ballast and did not provide after first loading.

One mechanical dial gage was placed on each tie to measure the deflection at the center of the ties. The gages were capable of measuring deflections to 0.0025 cm (0.001 in) sensitivity.

TESTING PROGRAM

One test was conducted without fabric and the other with fabric. Each test following a loading and unloading procedure required a total of 6 days. At various times during the testing, the loading wheel was stopped at each tie and the data from the dial and strain gages was recorded. The test procedure was as follows:

1. The first day of the test, 22.3 kN (5,000 lb) of vertical load was applied for 500 cycles. The load was then completely removed. A cycle is defined as one complete movement from one edge of tank to the other end and back.
2. The second day of the test, 22.3 kN (5,000 lb) of vertical load was applied for 275 cycles. The load was then completely removed.
3. The third day of the test was utilized for observing and recording the rebound of the system.
4. The fourth day of the test, 26.7 kN (6,666 lb) of vertical load was applied for 400 cycles. The load was then completely removed.
5. The fifth day of the test, 26.7 kN (6,666 lb) of vertical load was applied for 350 cycles. The load was then completely removed.
6. The sixth day of the test was utilized for observing and recording the rebound of the system.

After finishing the first test without the fabric, the ballast and the top 10.15 cm (4 in) of the soil were removed and replaced by new soil, placed and compacted as previously described. The fabric was then placed on top of soil. An initial tension was applied in the fabric by hanging weight. The fabric was covered with ballst and second test was performed.

TEST RESULTS

The results obtained from tests with and without the geotextile are now presented. The vertical moving loads for two series of tests were 22.3 kN (5,000 lbs) and 26.7 kN (6,666 lbs). These were chosen because they produce pressures in the soil layer close to that of real life (i.e., under railroad loading). The comparison from the later loading (that is from 26.7 kN) only will be presented in the paper.

The ties were numbered from 1 to 5 as shown in Figure 1 and Figure 6. The measurements were recorded at each tie immediately after the loading started, after loading to 250 cycles and 400 cycles. The load was then removed and the system allowed to rebound for twelve hours. The system was then reloaded and measurements recorded immediately after reloading, after loading to 500 cycles and 750 cycles. The loading wheel was stopped at each tie after each of above mentioned period, and readings from all gages were noted. Selected data for 26.7 KN load after 400 cycles and rebound readings after removal of the load for a period of twelve hours are presented in Figures 7 and 8. In Figure 8 the deflection readings presented are the maximum deflections and represent the deflection under the load (i.e., the deflection under tie 1 is the deflection when load was at tie 1 and deflection under tie 2 is deflection when load was at tie 2 and so on). Similarly Figure 9 presents the maximum deflection after 750 cycles and rebound readings after removal of the load for a period of twenty-four hours. Strains recorded from soil strain gage No. 2 during 26.7 KN loading period can be read from Table 1.

Table 1. Strains Obtained from Soil Strain Gage No. 2 During 6,666 lb (26.69 kN) Loading Period

Loading Period	Test without Fabric	Test with Fabric
Loading Started	0.0024	0.0029
After 250 Cycles	0.0048	0.0037
After 400 Cycles	0.0096	0.0042
Loading Restarted	0.0034	0.0024
After 500 Cycles	0.0045	0.0024
After 750 Cycles	0.0052	0.0045

The deflections obtained with and without the fabric of course were found to have similar patterns. A plot of load versus total deflections at the point where the load was acting upon, at different cycles of load is shown in Figures 10 and 11 for positions 1 and 3. Plots of the strain (total deflection at the point where the load was acting upon, divided by total length of rail 241.3 cm) is plotted against the number of cycles on a semi-logarithmic scale in Figures 12, 13 and 14 for positions 1 and 3. The results indicate the similar patterns and similar slopes of relation between strain and number of cycles (especially after 400 cycles). It is clear that larger strain occur in the subgrade without the geotextile than in the subgrade reinforced with geotextile.

CONCLUSIONS

A comparison of results from with and without geotextile indicate the following:

Total deflection of ties was reduced by about 30% when fabric was used.

From the tie deflection patterns, it can be seen that the subgrade behaves as an elastic foundation when reinforced with fabric. It takes about 450 cycles of loading for the soil unreinforced by fabric to exhibit the same behavior, i.e., to cause to elastic behavior. In other words the 450 cycles of loading cause a densification in the ballast-soil system which was equal to ballast-fabric-soil at the initial stage.

The investigation therefore proved that the geotextile due to its membrane action, caused the entire system to behave closer to an elastic foundation. Its response to loading therefore can be predicted. However it must be borne in mind that an investigation of a scaled structure (rail and ties) on a prototype subgrade cannot be directly applied to the field. However such an investigation increases the understanding of the mechanisms involved and can serve as a check to a numerical analysis scheme of the input parameters of the ballast-fabric-soil system are known.

ACKNOWLEDGEMENT

The financial support provided by the AMOCO Fabric Company for the investigation is deeply appreciated. Thanks are due to Anton Ketterer, technician in C.E. Department for assistance in building the test equipment.

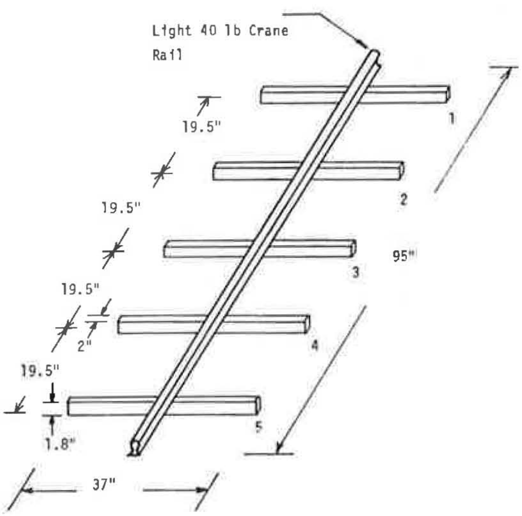

Figure 1. Light 40 lb Crane Rail with Five Oak Wood Ties. (1 in.=2.54cm, 1 lb=4.45N)

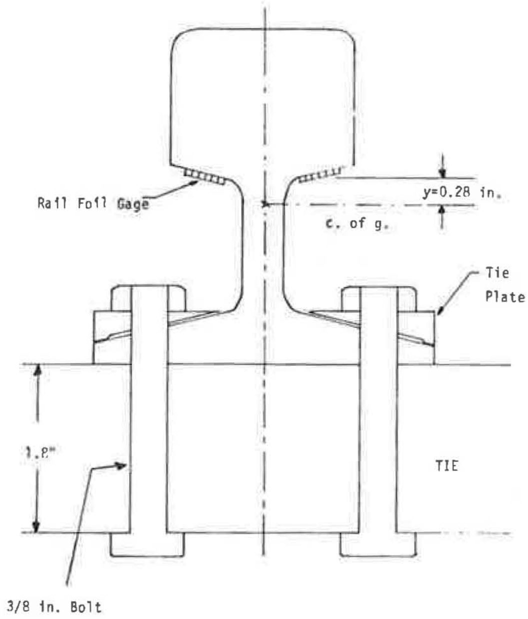

Figure 2. Light Crane Rail with Tie Plate and Rail Gages. (1 in.=2.54cm, 1 lb=4.45N)

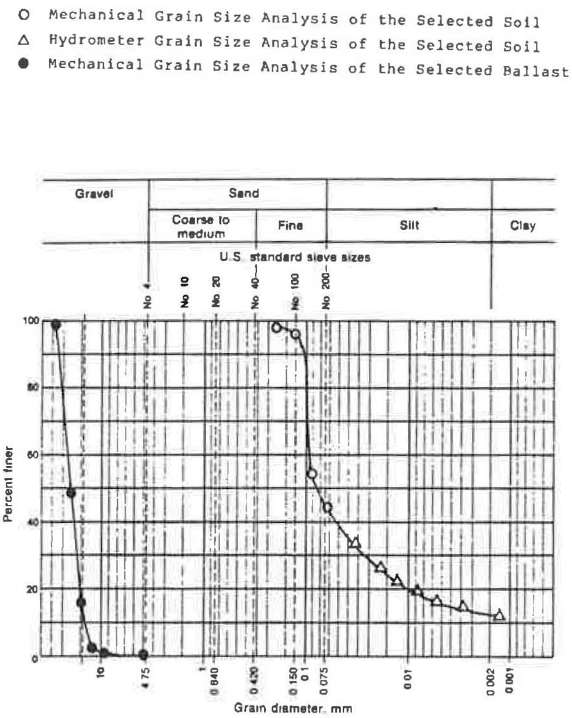

Figure 3. Grain Size Distribution Curve for the Soil and Ballast.

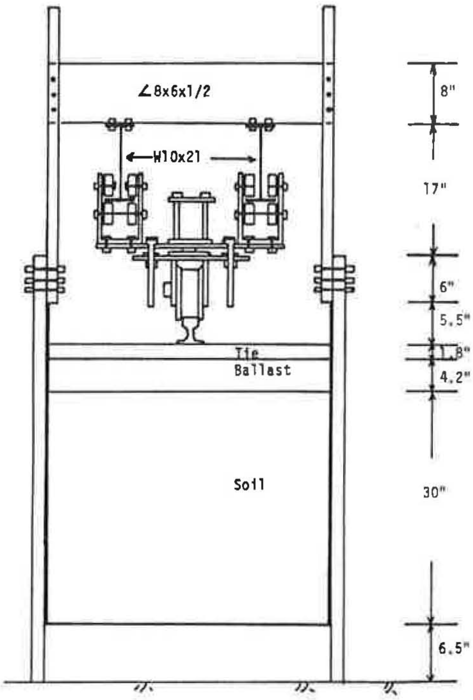

Figure 4. Loading Frame Front Profile.
(1 in.=2.54cm)

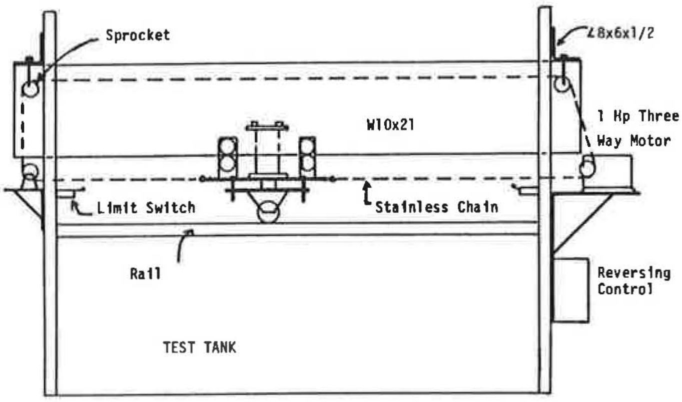

Figure 5. General View of the Electrical System of the Model Test Tank.

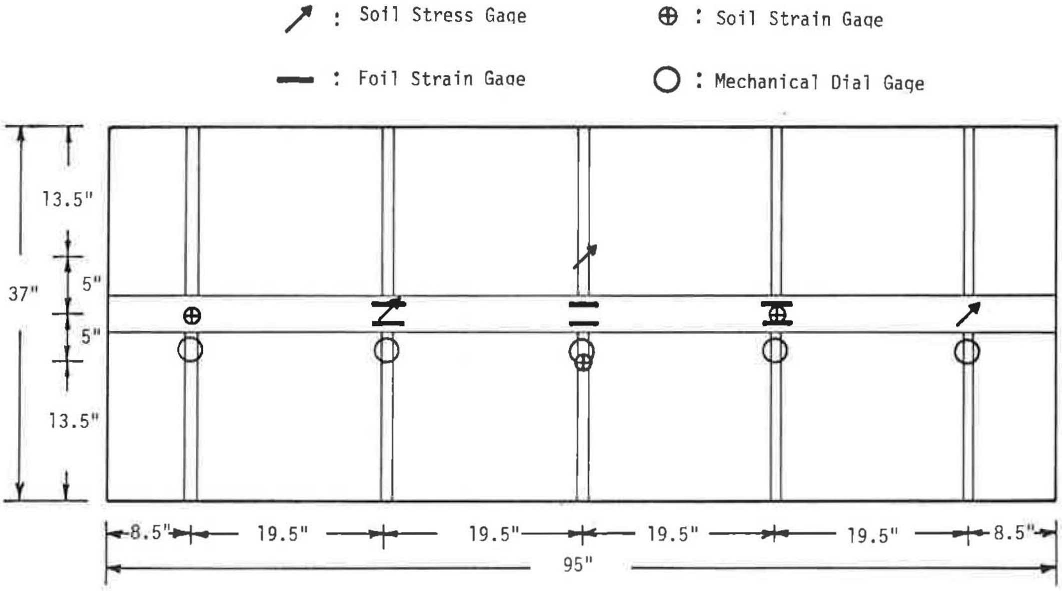

Figure 6. General View of Placement of Stress Strain Gages and Dial Gages.
(1 in = 2.54 cm)

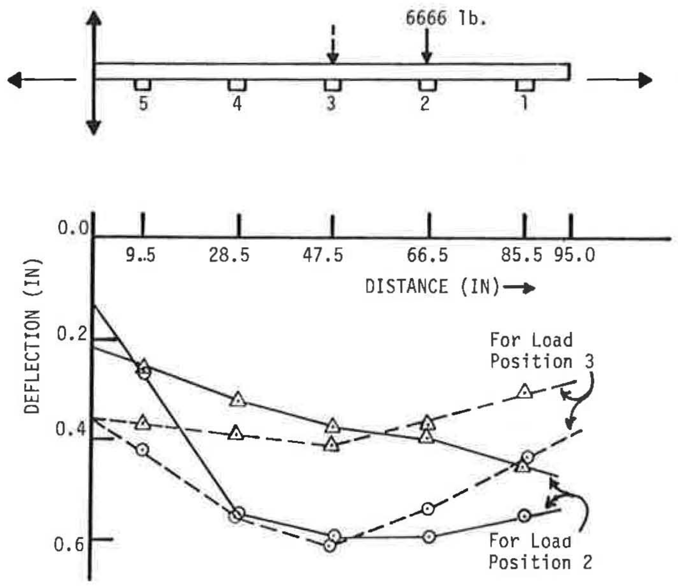

Figure 7. Tie Deflections for Load at Position 2 and 3 after 400 Cycles of Loading.

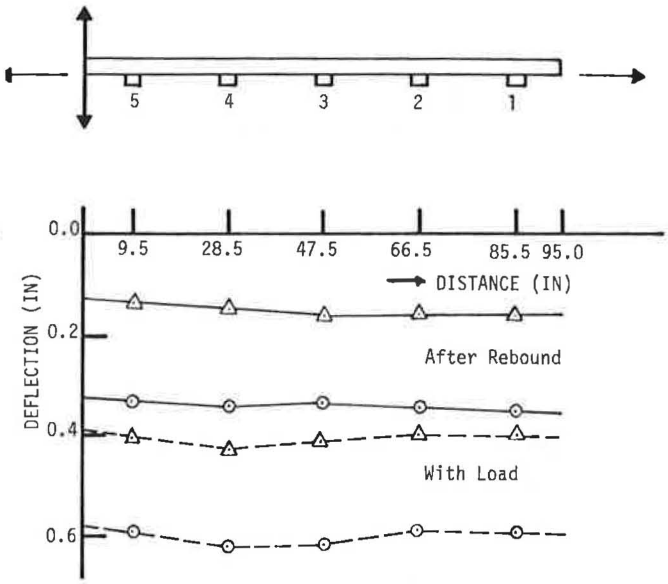

Figure 8. Maximum Deflection and Rebound After Twelve Hours

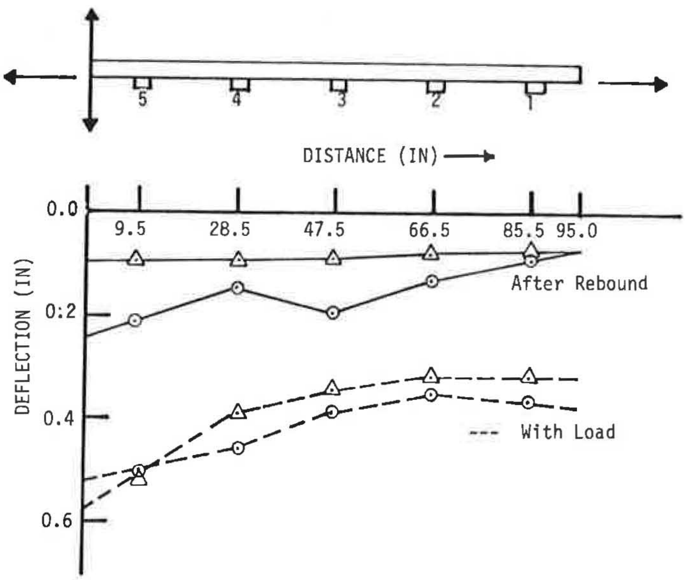

Figure 9. Maximum Deflection and Rebound After Twenty Four Hours.

PLEASE NOTE FOR ALL FIGURES ON THIS PAGE

△ Tests With Fabric

⊙ Tests Without Fabric

1 in. = 2.54 cm

1 lb. = 4.45N

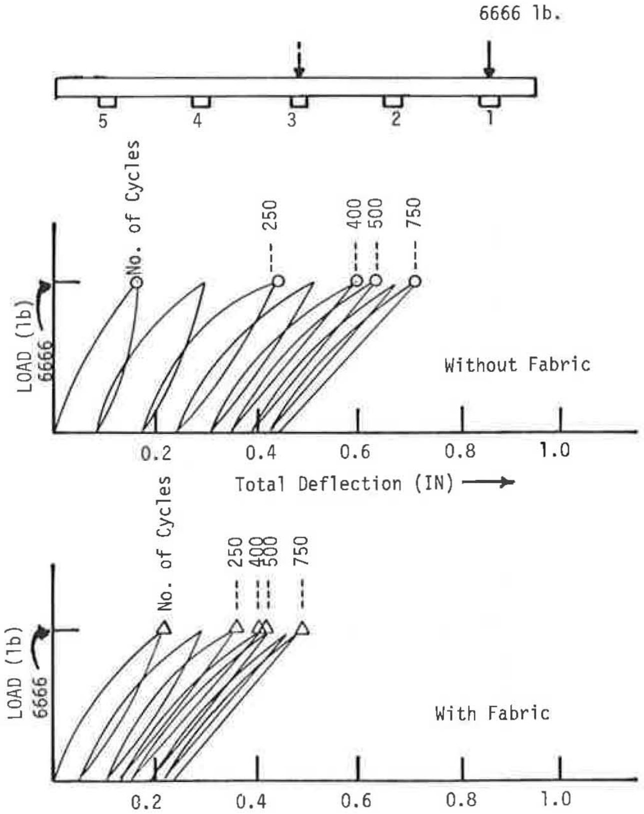

Figure 10. Total Deflection at Position 1 at Different Cycles

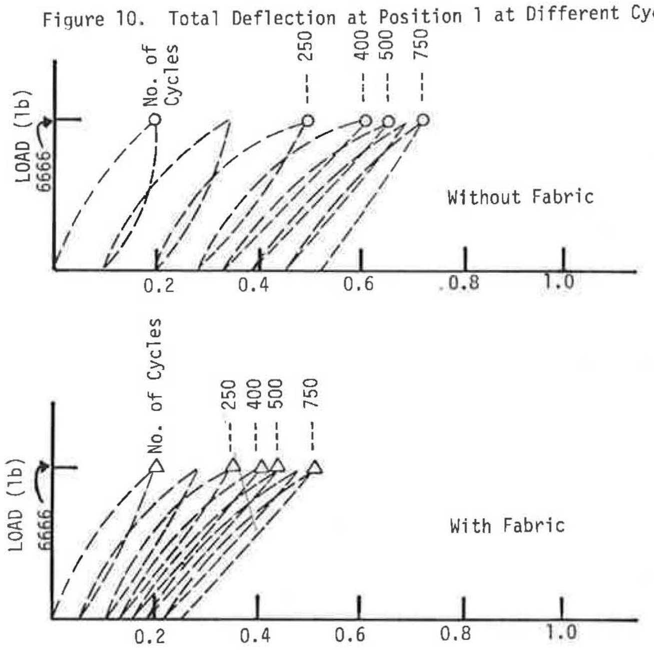

Figure 11. Total Deflection at Position 3 at Different Cycles.

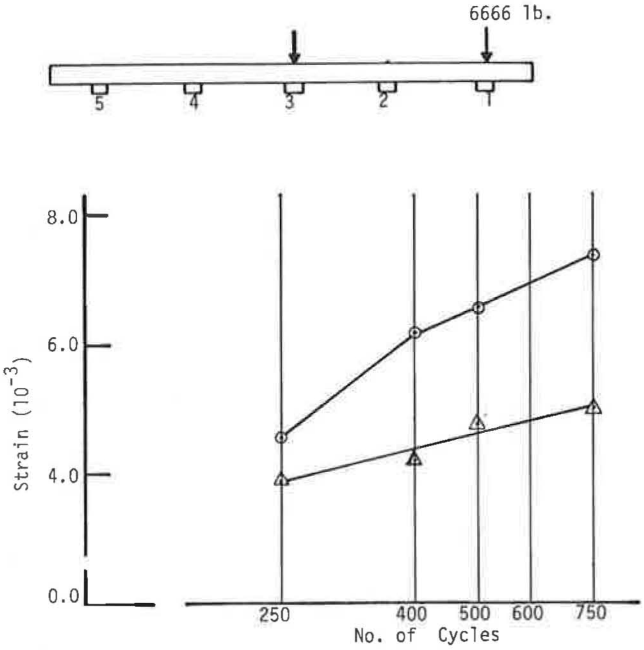

Figure 12. Strain at Position 1 Versus No. of Cycles

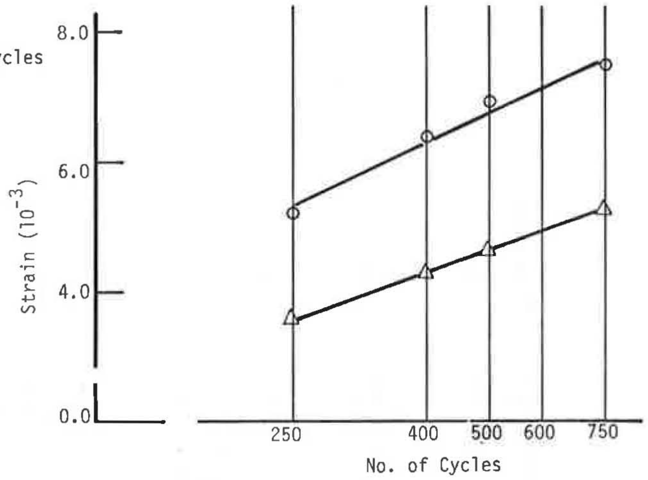

Figure 13. Strain at Position 3, Versus No. of Cycles

PLEASE NOTE FOR ALL FIGURES ON THIS PAGE

- △ Tests With Fabric
- ⊙ Tests Without Fabric
- 1 in = 2.54 cm
- 1 lb = 4.45N