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Evaluation of the Tensile Properties of Tenax Geogrid

Geophysical Systems Group
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LTRC

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Evaluation of the Tensile Properties of Tenax Geogrid

Technical Assistance Report Number 14

by

Hadi Shirazi

Louisiana Transportation Research Center
Louisiana Department of Transportation and Development
4101 Gourrier Ave.
Baton Rouge, LA 70808
Tel: (504)767-9149 Fax: (504)767-9108

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INTRODUCTION

This report summarizes the results of a geogrid testing program conducted by the Geophysical Systems Research Group of the Louisiana Transportation Research Center (LTRC). The testing program was designed to determine the adequacy of the Tenax™ multilayered geogrids to meet the DOTD generic specifications for subgrade stabilization. This study, initiated at the request of the DOTD Pavement and Geotechnical Design Engineer, tested Tenax MS220, MS330, and MS500 geogrids. The MS220, MS330, and MS500 are two-layered, three-layered and five-layered biaxially oriented polypropylene grids, respectively.

The DOTD generic specification for geogrid used as subgrade reinforcement requires a minimum tensile modulus of 14,000 lb/ft tested in accordance with GRI GG1-87. This test method determines the tensile modulus from the tensile test results of a single rib test. The result of the single rib test is then multiplied by the number of ribs within one foot of geogrid. Because the Tenax geogrid is a multilayered system, the number of ribs within one foot depends on the number of layers per each type geogrid. The appropriateness of this test for a multilayered system needed to be addressed. The question of geogrid interaction of the multilayered system was also a concern to the designers.

The testing program was thus designed with cooperation of the pavement and geotechnical design section to attempt to use laboratory testing to answer the questions of tensile modulus and geogrid interaction. Tensar™ BX1100 and BX1200 geogrids were also tested in this program for control sample results.

The DOTD Generic Specifications for subgrade reinforcement is presented in the Appendix.

OBJECTIVE

The objective of this study was to evaluate the multilayered Tenax geogrid for use as subgrade stabilization reinforcements. To meet these objectives, laboratory testing included wide width tensile testing in accordance with ASTM 4595, direct shear testing using a large 27 inches by 27 inches direct shear box, and confined extension tests using a large pullout box.

The data obtained from testing Tenax geogrids and Tensar control geogrids allow the current methods of specifications to be evaluated for use on multilayered systems.

METHODOLOGY

Testing Program

A laboratory testing program was conducted on the Tenax multi-layered biaxial geogrids and Tensar biaxial geogrids. The summary of testing is shown in table 1. The testing program consisted of the following tests:

1. Wide width tensile tests were conducted on Tenax MS 220, MS 330, MS 500, and Tensar BX1100 and BX1200 geogrids. These tests were conducted on specimens of average widths of 6 to 8 inches according to the ASTM Wide Width test method D4595.

2. Wide width tensile tests on the single layers of each Tenax geogrid type were performed. The Tenax geogrids were tested with multi-layered samples as appropriate for each type. The strength of the multi-layered geogrid was compared with a multiplication of the strength of the single layer by the number of layers.

3. Direct shear tests were conducted on MS 500, Tensar BX1200, and unreinforced soil placed between a silty-clay A-7 soil and a stone-base soil. The interface shear resistance was close to that of Tensar BX1200 tested in the same soil and testing conditions. Moreover, the interface friction angles of both types of grids with soil were similar to the angle of friction of the soil-soil interface without geogrid.

4. Confined extension tests were performed on MS 500 and Tensar BX1200 placed between a silty-clay A-7 soil and stone-base soil. The Tenax MS 500 was chosen for this test due to the numerous amounts of the layers in the Tenax sample. The MS 500 has five layers.

Table 1

Summary of the testing program on the Tenax and Tensar geogrid.

Test	Geogrid	No. of Tests	Notes
Wide Width Tensile Tests	MS 220 [2 layers], and	6	
	BX1100 MD [(1)]	6	
	XD	6	
	MS 330 [3 layers], and	7	
	BX1200 MD	6	
	XD	6	
	MS 500 [3 layers] MD	11	
	XD	11	
Wide Width Tensile Tests	MS 220 [1 layer] MD	16	
	XD	14	
	MS 330 [1 layer] MD	12	
	XD	17	
	MS 500 [1 layer] MD	18	
	XD	18	
Direct Shear Tests	- Tenax MS 500	3	Confining pressures 2 psi, 4 psi, and 6 psi.
	- Soil-Soil [No geogrid]	3	
	- Tensar BX1200	3	
Confined Extension Tests	- Tenax MS 500	1	Confining pressure 5 psi.
	- Tensar BX1200	1	

(1) MD: Machine Direction   2) XD: Cross Direction

Testing Equipment and Program

The United Machine at LTRC was used in the wide width tensile tests. The machine applied constant controlled extension-rate tensile load on the specimen. Extension-rate, tensile strength, and displacement were recorded on an *x-y* plotter connected to the machine and were displayed on the digital readout system.

The large direct-shear box was used in direct-shear tests. The box consisted of an upper shear box of 27 inches wide, 27 inches long and 12 inches high. The upper box was clamped to plates connected to a hydraulic ram that applied a controlled displacement rate. The upper box was sheared on the top of a lower box of 60 inches long and 12 inches high. Normal pressure was applied by an air bag confined in the top of the box. A schematic diagram of the large shear box is shown in figure A-1 in the appendix.

The LTRC large pullout box was utilized in the confined extension testing of the MS 500 geogrid. A schematic diagram of the box is shown in figure 2 in appendix A. As in the direct shear tests, the geogrid specimen was placed on the top of the silty-clay soil and was clamped to the end of the box. A view of the geogrid specimen in the box is shown in figure 3 in appendix A. Stone-base soil was placed on the top of the specimen. The front of the specimen was clamped to the hydraulic system that applied an extension load at a constant rate. The test was conducted at a confining pressure of five psi.

Testing Procedure

Wide width tensile tests:

Each test specimen was cut to include as many eight inch wide longitudinal strands of the grid as possible. The length of the specimen was chosen to reach an ideal 2:1 width to length ratio. The actual length of the specimen was dependent upon the spacing of the transverse members of each type of the geogrid.

In order to adjust the tensile rate of the United Testing Machine for strain measurement, the test specimen was measured in machine direction and cross direction when clamped. The rate of loading was dependent on the height of the test sample. The tensile load was applied at the specified rate until the specimen ruptured.

Tensile load and strain were recorded for each test and plotted on the *x-y* plotter. Test results were discarded for the specimens that ruptured near the edge of the jaw of the clamps.

Direct shear tests:

Silty-clay type A-7 soil was placed in the lower half of the direct shear box . The soil was compacted in four inch lifts. Density and moisture contents measurements are shown in appendix B.

The 27 inch wide geogrid specimen was placed on the bottom of the upper shear box. Stone-base aggregate was placed and compacted above the grid. Gradation analysis of the stone is shown in appendix B.

Direct shear test were run with normal pressures of two psi, four psi, and six psi applied on the top of the upper box. The upper box was then pulled at a constant rate and the shear strain-stress were recorded.

Confined-extension test:

Confined extension tests were performed with the same types of soils used in the direct shear tests.

The geogrid specimen had dimensions of ten inches wide by three feet long. The specimen was placed on the top of the silty clay soil and was clamped at the back of the pullout box. The front end of the specimen was clamped to the plates and connected to the hydraulic machine.

Tests were conducted at a confining pressure of five psi on the Tenax MS 500 and Tensar BX1200 geogrids.

DISCUSSION OF RESULTS

The results of the Wide width tensile tests, performed in accordance with ASTM D4595 on Tenax MS 220, MS 330, MS 500, and Tensar BX1100, and BX1200 geogrids are shown in tables 2 and 3. The results of load verses percent strain are shown in figure C-1 to figure C-10 in appendix C. The results present the average values of tests conducted on Tenax multi-layered geogrids and Tensar geogrids applying load in machine direction and cross direction. The values in the table were calculated for unit width of the grid. Ultimate strength, strength at 5% strain, and tensile modulus at 2% were presented. From the curves, (appendix C) the 2% strain was measured, and 2% tensile modulus was calculated. The DOTD Construction Specification provides value for tensile modulus at 2% strain. The DOTD Construction Specification value is based on testing specifications of the Geosythetics Research Institute (GRI-GG1 87). The results of both geogrids met or exceeded the minimum value required in the DOTD Construction Specification. The DOTD Construction Specification is shown in appendix D.

The results of the Wide width tensile tests on a single layer of the MS 220 geogrids are compared with the results of the double layer MS 220 type. Results show that the strength of the multi-layered Tenax geogrids are not equal to the strength of the single layer multiplied by the number of layers. Table 4 shows the results of single layer and multi-layer Tenax geogrids. Figure 1 show the failures point on both Tenax MS 220 and Tensar BX 1100.

Direct shear tests using applied normal stresses of two psi, four psi , and six psi were conducted on Tenax MS 500 and Tensar BX1200. Results of shear stress verses normal stress for the Tenax geogrid are presented in figure 2. Figure 3 compares these results with similar shear tests conducted on soil-soil interface without geogrid and on soil-Tensar BX1200 at the interface. These results showed that the efficiency factor (soil-geogrid friction over soil-soil friction) is close to unity and that geogrids did not affect the frictional shear resistance at the interface.

Confined-extension test were conducted on the Tenax MS 500 geogrid and Tensar BX1200 in the cross direction. These tests were also conducted on the geogrid placed between a silty clay A-7 soil at the bottom of the box and stone-base layer at the top. The test was conducted on a grid specimen of one foot wide and three foot long at a confining pressure of five psi. The results of the test MS 500 are shown in figure 4. The results with a similar test conducted on the Tensar BX1200 are shown in figure 5. The results on both Tenax and Tensar geogrids show that the ultimate confined strength of the reinforcements are slightly higher than its ultimate wide width strength with lower elongation at peak strength due to confinement.

Table 2

Tensile test results [1]

	Unit Width Max. Strength (lb/ft)		Strength @ 5% Strain (lb/ft)		Tensile Modulus@ 2% Strain (lb/ft)	
	MD [5]	XD [5]	MD	XD	MD	XD
MS 220 [2]	890.7	1,419.7	706.0	1,109.0	17,063.0	22,515.0
MS 330 [3]	1,508.0	1,923.0	989.0	1,436.0	21,625	31,100
MS 500 [4]	2,064.0	1,813.6	1,047.0	1,027.0	25,076	20,076

[1] Test Method: Wide Width Tensile Test ASTM (D4595)

[2] Test results are the average values of six tests

[3] Test results are the average values of seven tests

[4] Test results are the average values of 11 tests

[5] MD: Machine Direction (longitudinal to the roll)

XD: Cross Machine Direction (across roll width)

Table 3

Tensile test [1] results [2]

	Unit Width Max. Strength (lb/ft)		Strength @ 5% Strain (lb/ft)		Tensile Modulus @ 2% Strain (lb/ft)	
	MD [3]	XD [3]	MD	XD	MD	XD
BX 1100	1,018.0	1,652.3	627.9	957.9	16,729.0	24,406.0
BX 1200	1,352.1	2090.0	916.7	1492.9	23,375.0	33,590.0

(1) Test results are the average values of six tests

(2) Test Method: Wide Width Tensile Test ASTM (D4595)

(3) MD: Machine Direction (longitudinal to the roll)

XD: Cross Machine Direction (across roll width)

Table 4

Tensile test results [1] on Single layer and multi-layer Tenax

	Grid Type on Tenax	Unit Width Max. Strength (lb)		Strength @ 5% Strain (lb)	
		MD	XD	MD	XD
MS 220	Single Layer [2]	272.0	454.4	210.0	330.0
	Multi-layer [3]	509.0	873.0	403.0	693.0
MS 330	Single Layer [2]	297.7	422.0	164.0	293.0
	Multi-layer [3]	861.0	1289.0	534.0	874.0
MS 500	Single Layer [2]	286.0	243.0	155.0	147.0
	Multi-layer [3]	1,238.3	1,088.2	625.0	588.0

(1) Test Method: Wide Width Tensile Test ASTM (D4595)

(2) Test results are the average values of twenty tests

(3) Test results are the average values of eight tests

(4) MD: Machine Direction (longitudinal to the roll)

XD: Cross Machine Direction (across roll width)

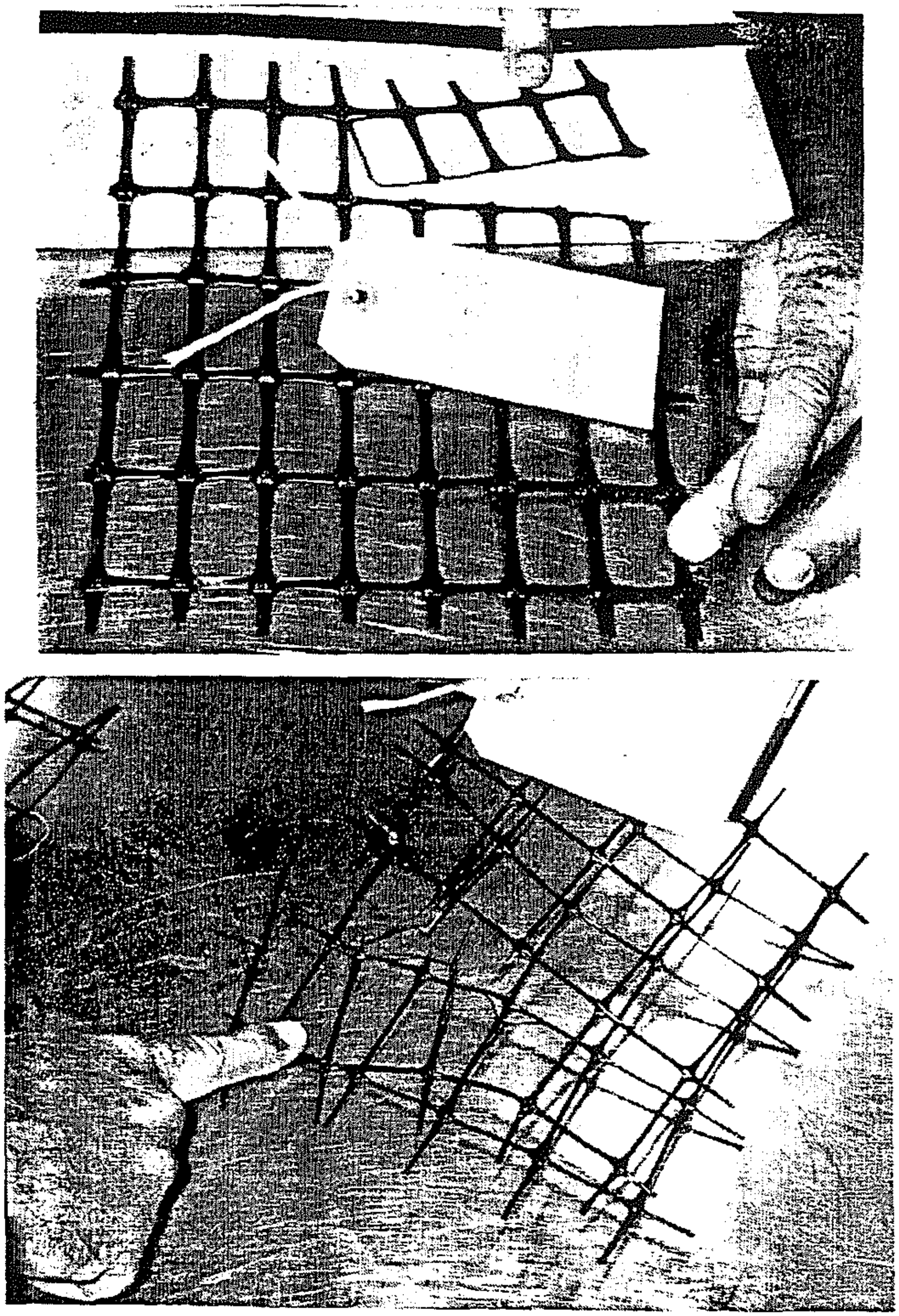

Figure 1

Failure point on Tenax MS 220 and Tensar BX 1100, machine direction

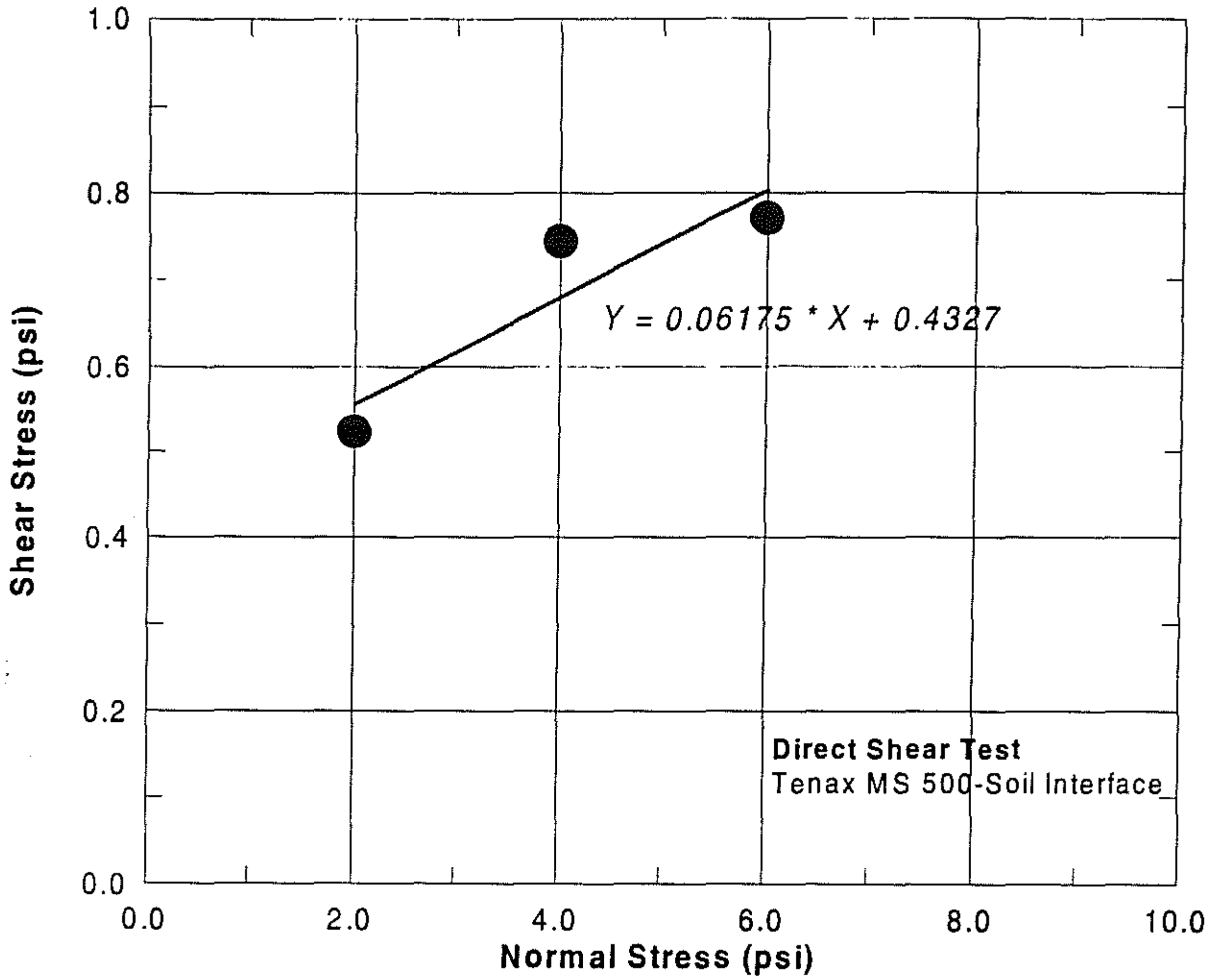

Figure 2

Direct shear test results on the tenax MS 500 geogrid

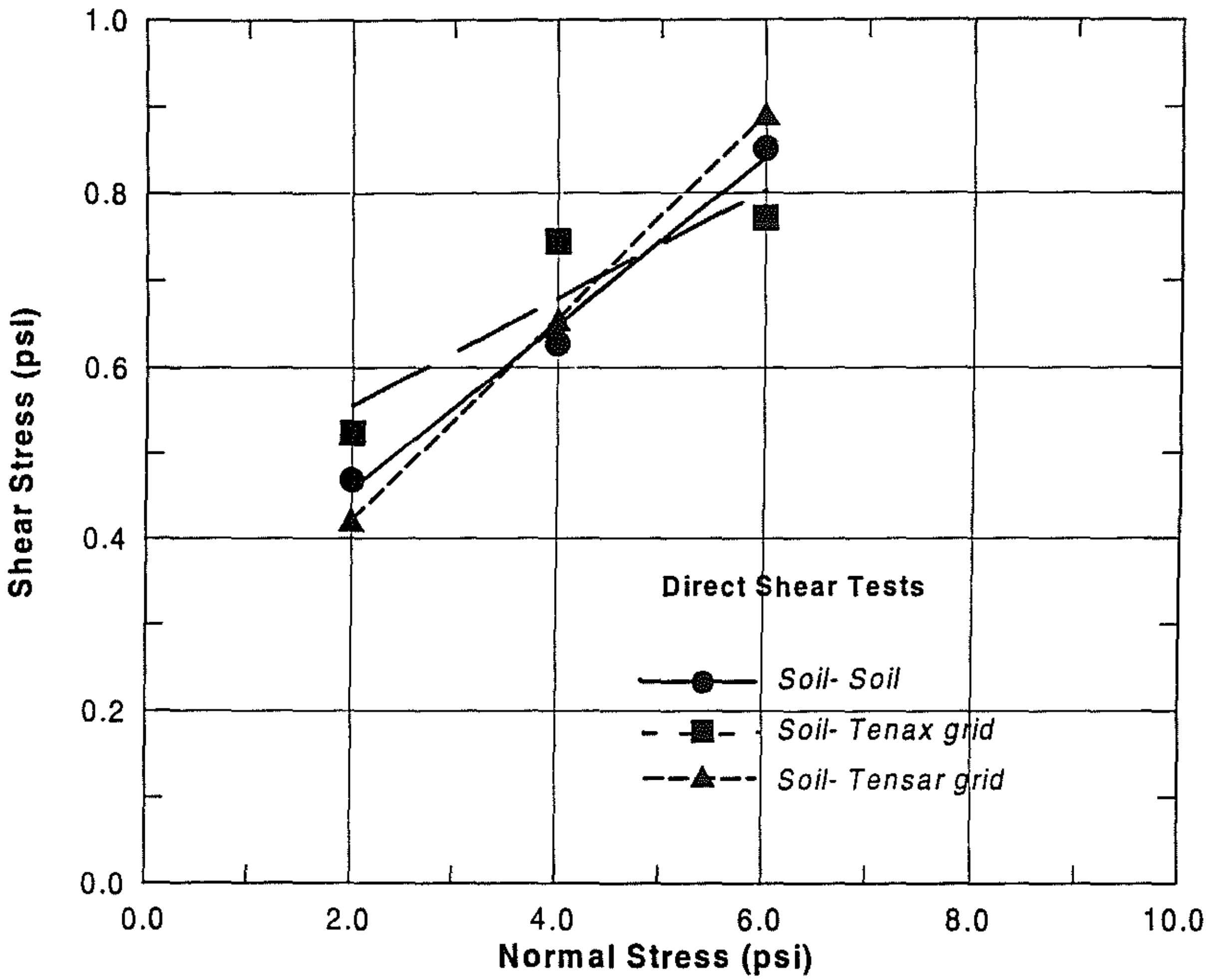

Figure 3

Comparison of direct shear test results

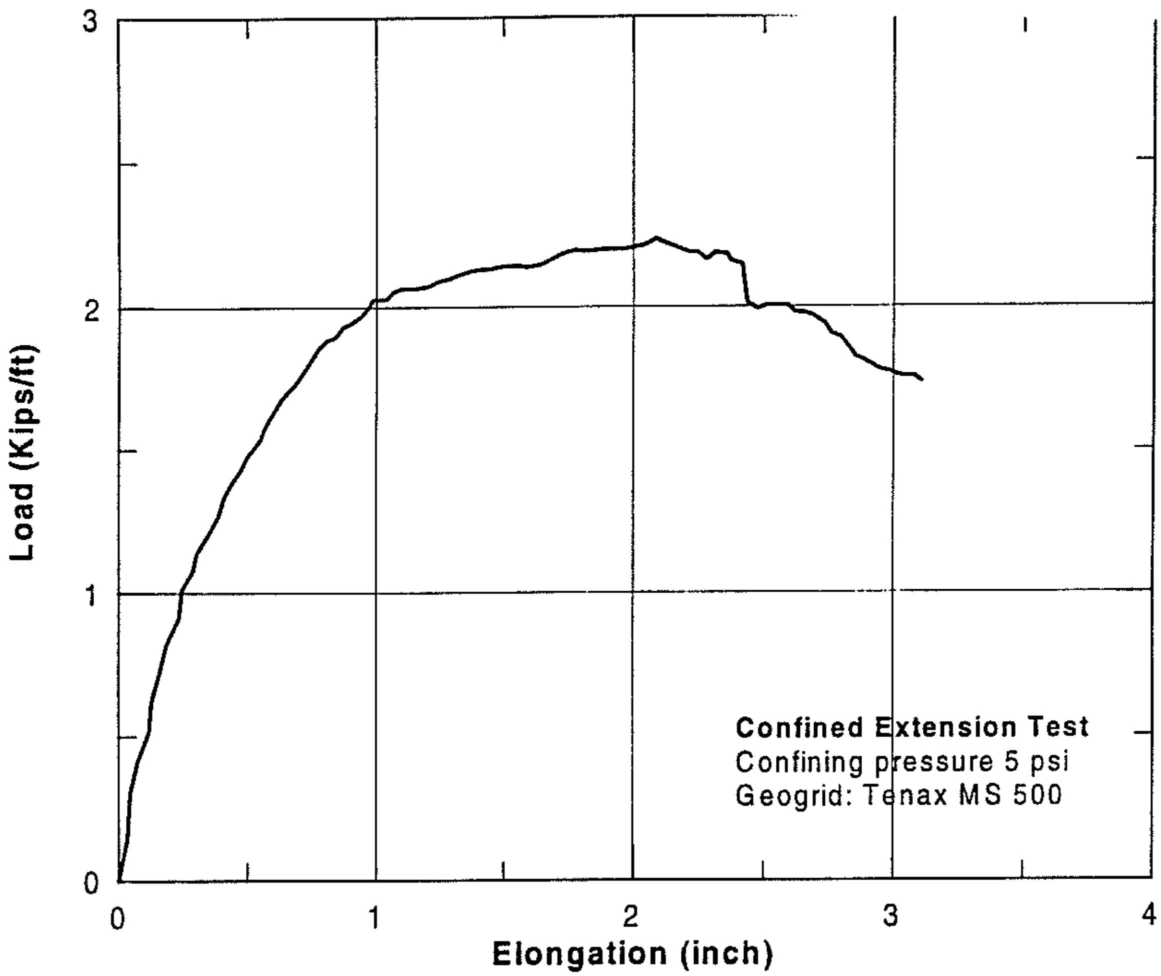

Figure 4.

Confined extension test results on the Tenax MS 500 geogrid

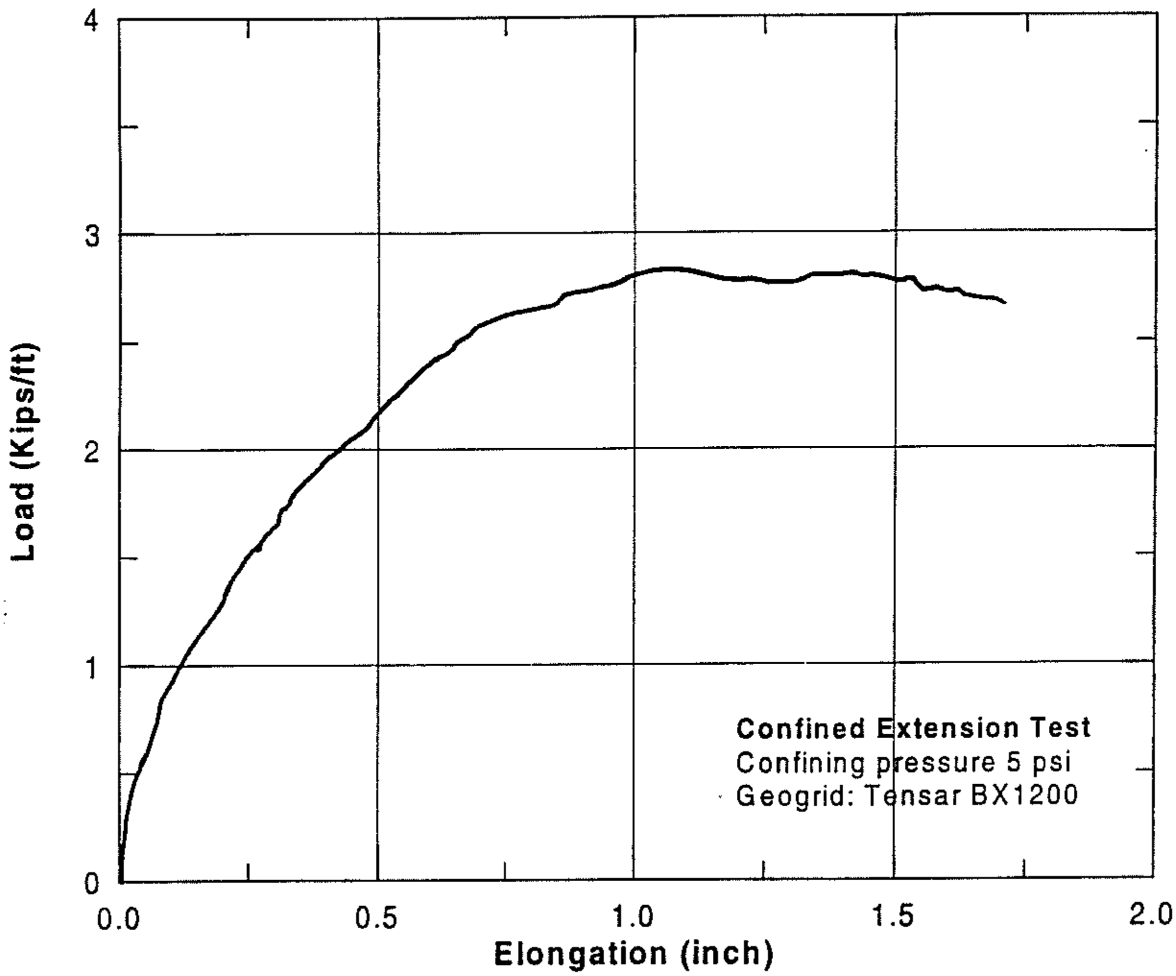

Figure 5

Confined extension test results on the tensar BX 1200 geogrid

CONCLUSIONS AND RECOMMENDATIONS

All Tenax MS 220, MS 330, MS 500, and Tensar BX 1100 and BX 1200 geogrids met the requirement of DOTD Construction Specifications value on 2% tensile modulus. DOTD Construction Specification requires a minimum tensile modulus of 14,000 lb/ft in accordance with the Geosynthetics Research Institute (GRI GG1-87). Based on the wide width tensile tests of ASTM 4595, all Tenax and Tensar geogrids met the requirements of 14,000 lbs/ft.

The result showed that the strength of the multi-layered Tenax geogrids is not equal to the strength of the signal layer multiplied by the number of layers. The GRI GG1- 87 gives the value of tensile modulus at 2% strain. The GRI GG1-87 test is used to determine the single rib tensile behavior of the geogrid. From the results of the single rib test, the full width geogrid strength is determined. However, multi-layered geogrids such as Tenax can not be modeled accurately from a single rib test. Therefore, it is recommended to use ASTM Wide width tensile test D4595 in DOTD Construction Specifications rather GRI GG1-87. It would give actual tensile strength and tensile modulus values for multi-layered and single layered geogrid.

Results of direct shear testing show both the Tenax and Tensar geogrids compare favorably with the results of the soil-soil interface friction without reinforcement.

The results show that the ultimate strength of the grid in the confined condition were slightly higher than its wide width tensile strength. Confined extension strength was mobilized at lower displacement due to confinement.

APPENDIX A

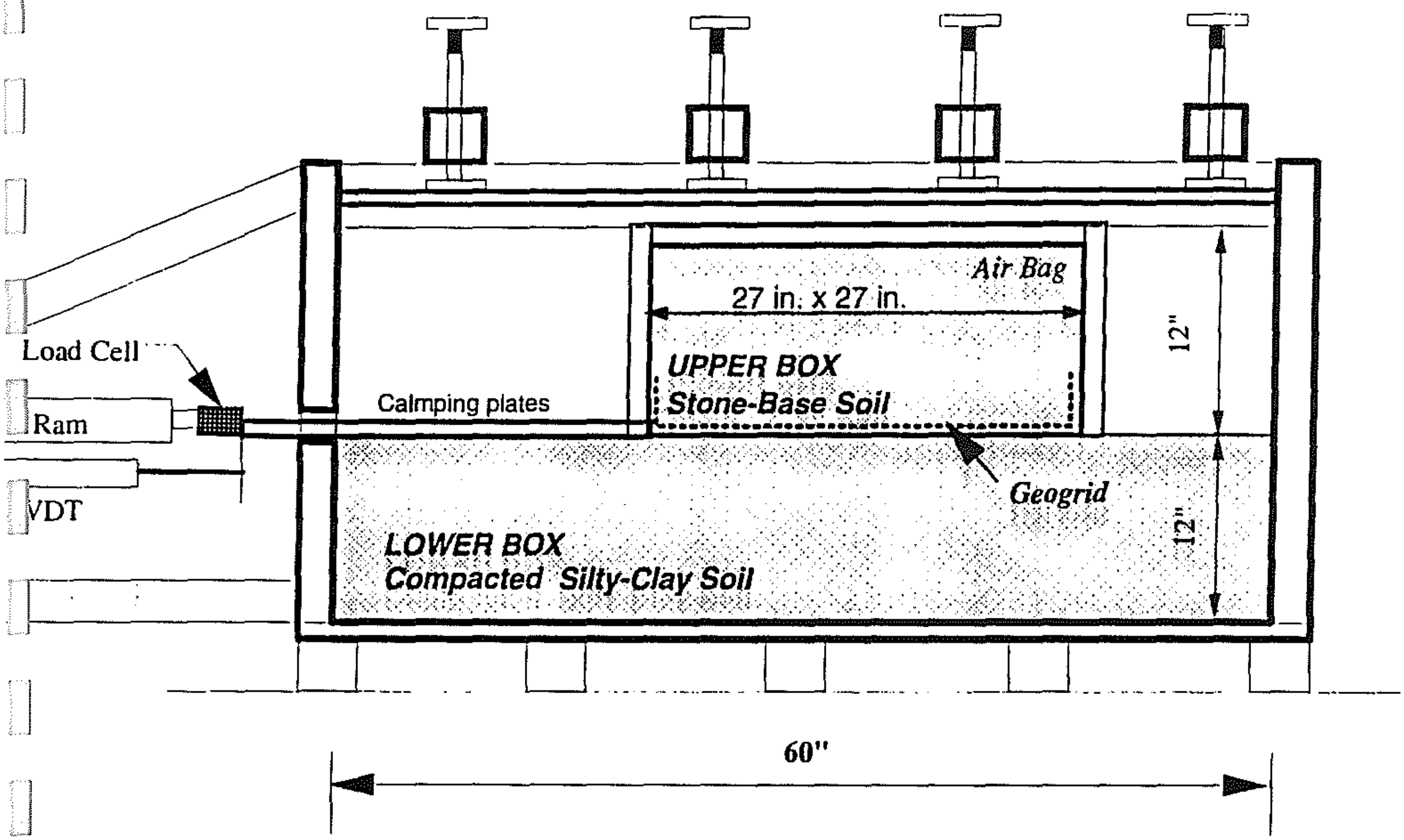

Figure A-1

Schematic of the large direct shear box

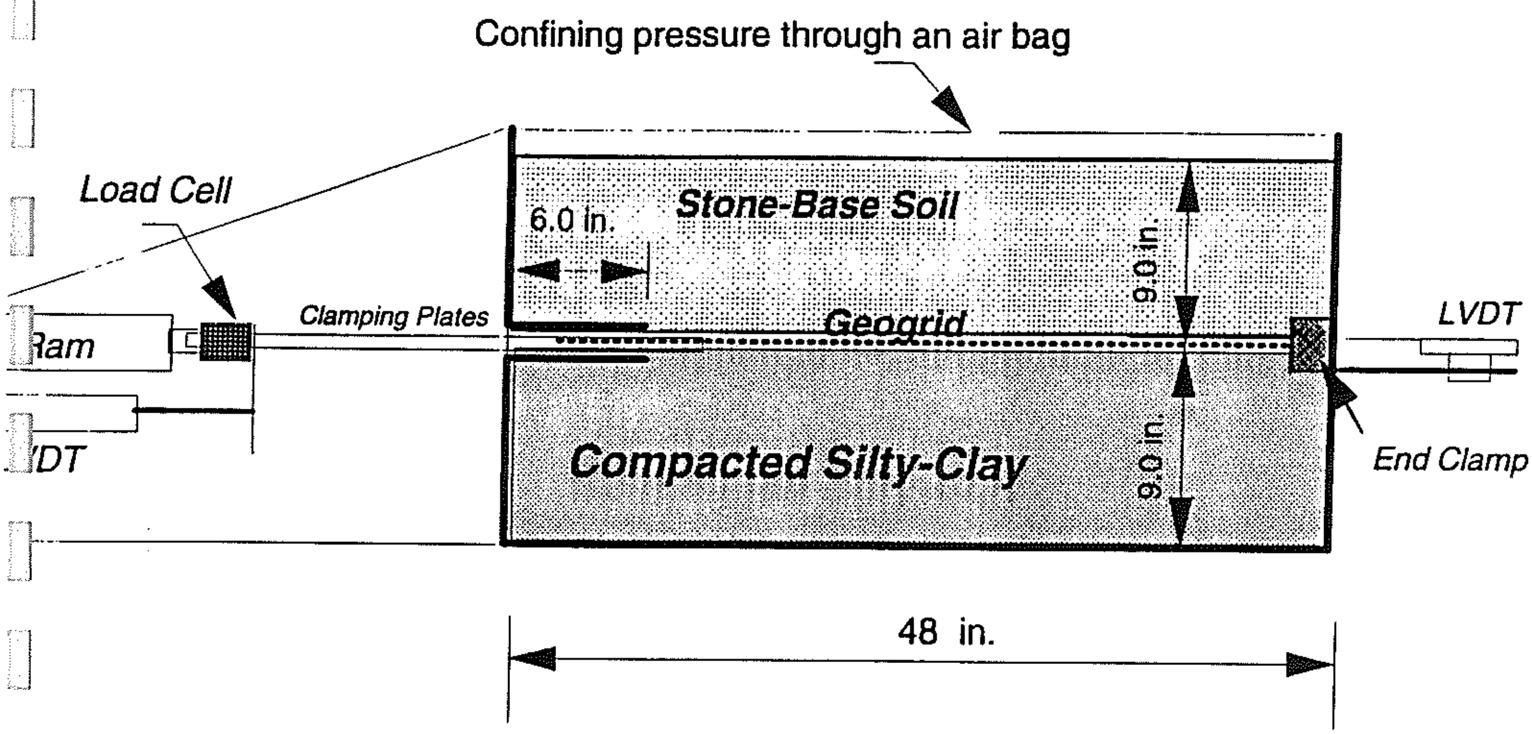

Figure A-2

Schematic view of the confined-extension test

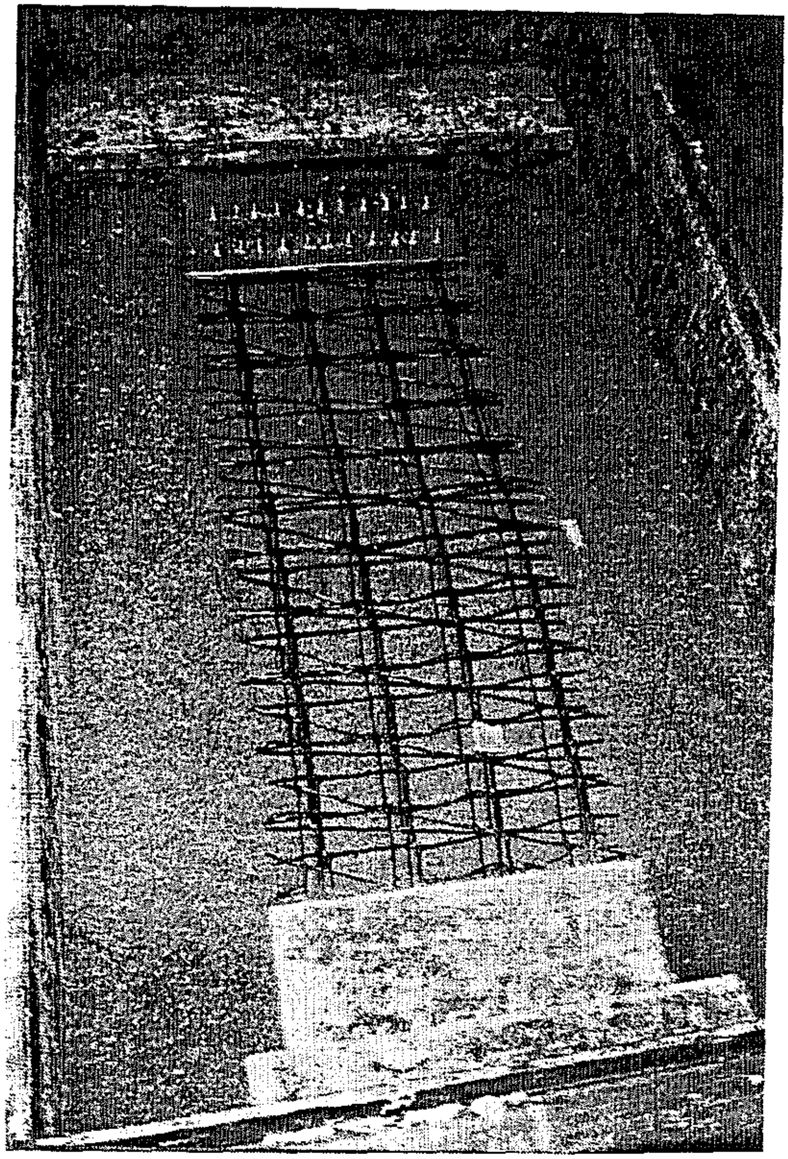

Figure A-3

Placement of the geogrid in confined-extension tests

APPENDIX B

Geosynthetics Engineering Research Laboratory (GERL)

Laboratory Moisture Content Meaurement

Test : Direct Shear tests - Texas

Date :

Description : Silty Clay A-7 Soil

Cup No.	wt. of cup	Wt. of (wet soil + cup)	Wt. of (dry soil +cup)	Wt. of Water	Wt. of dry soil	Water Content (%)
8133	28.82	113.28	98.42	14.86	69.60	21.35
18	24.80	151.95	129.75	22.20	104.95	21.15
8106	28.41	102.69	89.92	12.77	61.51	20.76
318	24.76	123.26	106.02	17.24	81.26	21.22
8100	28.18	160.95	137.73	23.22	109.55	21.20
44	24.40	104.46	90.29	14.17	65.89	21.51

Figure B-1
Direct shear moisture content measurement

Moisture Density Measurements *(Nuclear Density Gage)*

Test : Confined Extension - Tenax
Date : June 96

Layer	Point	Water Content (%)	Soil Dry Density (pcf)	Soil Wet Density (pcf)	Notes
	1	25.6	95.3	119.6	
	2	25.1	97.9	122.5	
	3	22.6	97.7	119.8	
	4	22.6	97.8	119.8	
	5	26.6	93.0	117.8	
	6	26.3	92.6	117.0	

Layer	Point	Water Content (%)	Soil Dry Density (pcf)	Soil Wet Density (pcf)	Notes
	1				
	2				
	3				
	4				
	5				
	6				

Figure B-2
Moisture density measurements (Nuclear density gage)

Moisture Density Measurements *(Nuclear Density Gage)*

Test : Direct Shear Tests - Tenak
Date : June 96

Layer	Point	Water Content (%)	Soil Dry Density (pcf)	Soil Wet Density (pcf)	Notes
	1	18.7	86.9	103.2	
	2	18.8	87.9	104.4	
	3	17.6	92.6	108.9	
	4	19.7	86.4	103.4	
	5				
	6				

Layer	Point	Water Content (%)	Soil Dry Density (pcf)	Soil Wet Density (pcf)	Notes
	1				
	2				
	3				
	4				
	5				
	6				

Figure B-2
Moisture density measurements (Nuclear density gage)

5-8-96

LCH 03-22-1011
REV. 10/75

MECHANICAL ANALYSIS OF AGGREGATE

MATERIAL ALF STONE PROJECT OR P.O. ______

TYPE OR SIZE ______ SAMPLE NO. ______

SIEVE	WEIGHT	PERCENT	PERCENT	PERCENT COARSER	SIEVE	PERCENT PASSING
2½ INCH			****		2½ INCH	
2 INCH			****		2 INCH	
1¾ INCH	0	0	****	0	1¾ INCH	100.
1½ INCH			****		1½ INCH	
1 INCH	5.1	5.46	****	5.46	1 INCH	94.54
¾ INCH	5.7	6.10	****	11.56	¾ INCH	88.44
5/8 INCH			****		5/8 INCH	
½ INCH	SPLIT				½ INCH	
3/8 INCH	~~REDUCE TO 8.12~~				3/8 INCH	
NO. 4	2.45	30.17	26.68	38.24	NO. 4	61.76
PASS NO.		****	****	****	NO. 7	
ACC. TOTAL		****	****	****	NO. 10	
INITIAL DRY TOTAL WT.	116.21	% DIFF.			NO. 16	
	WEIGHT	PERCENT	PERCENT		NO. 30	
NO. 8					NO. 40	10.07
NO. 10					NO. 50	
NO. 16					NO. 60	
NO. 20					NO. 100	
NO. 30					NO. 200	3.34
NO. 40	97.26	83.69	51.69	89.93	NO. 270	
NO. 50					DECANT. LOSS	
NO. 80					FOREIGN MATTER	
NO. 100					LIQUID LIMIT	
NO. 200	12.67	10.90	6.73	96.66	PLASTIC INDEX	
NO. 270					SAND EQUIV.	
PASS NO.		****	****	****	SPEC. GRAVITY	
DECANT. LOSS		****	****	****		
ACC. TOTAL		****	****	****		

INITIAL DRY TOTAL WT. ______ DRY WT. AFTER WASH ______ % DIFF. ______

DELETERIOUS MTL.: ______ COLORIMETRIC TEST: ______

TESTED BY: [illegible] DATE:

CK'D. BY: DATE:

NOTIFIED: DATE:

REMARKS:

LAB. NO.

Figure B-3
Mechanical Analysis of Aggregate

APPENDIX C

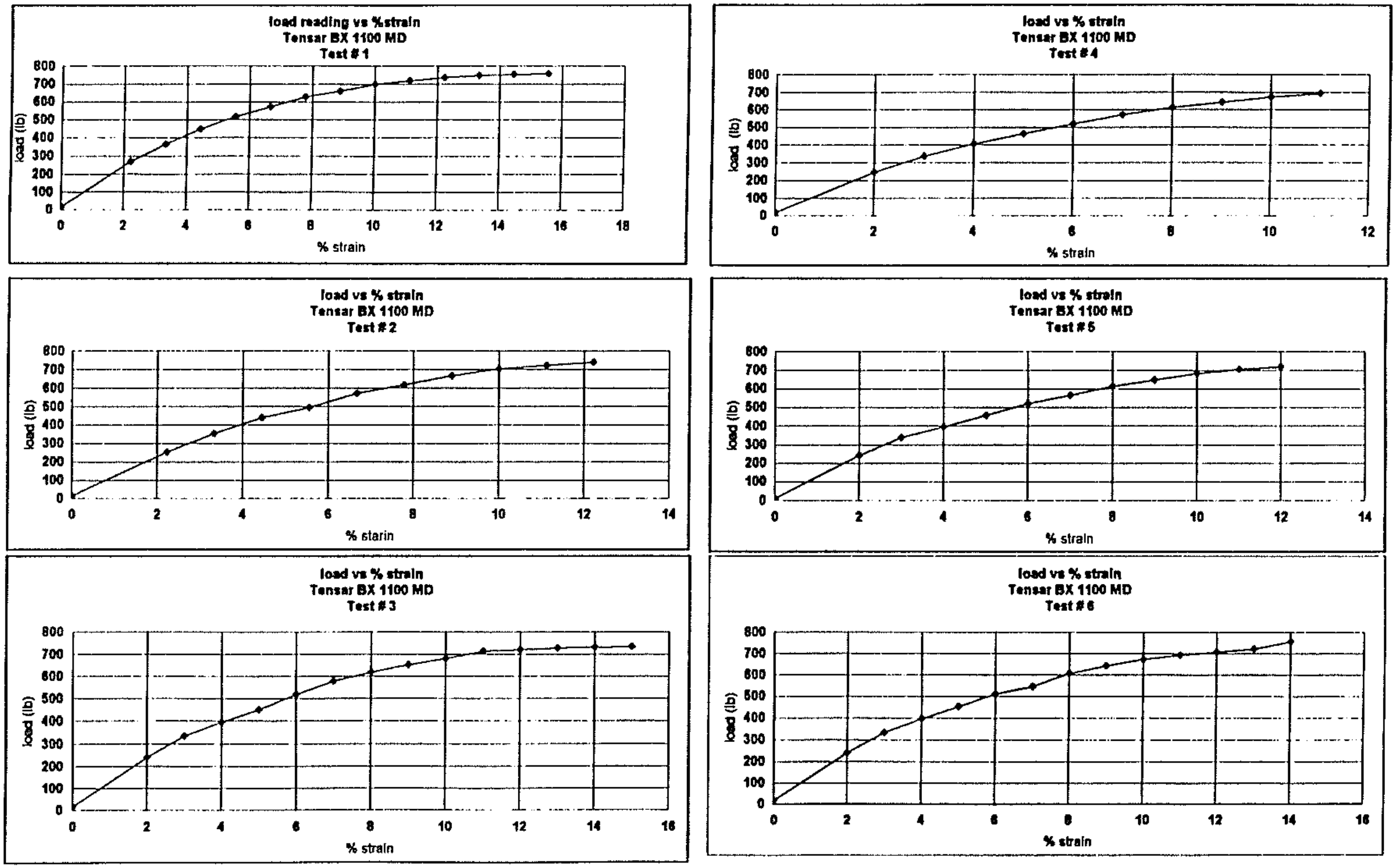

Figure C-1
Load vs. strain Tensar BX1100 machine direction

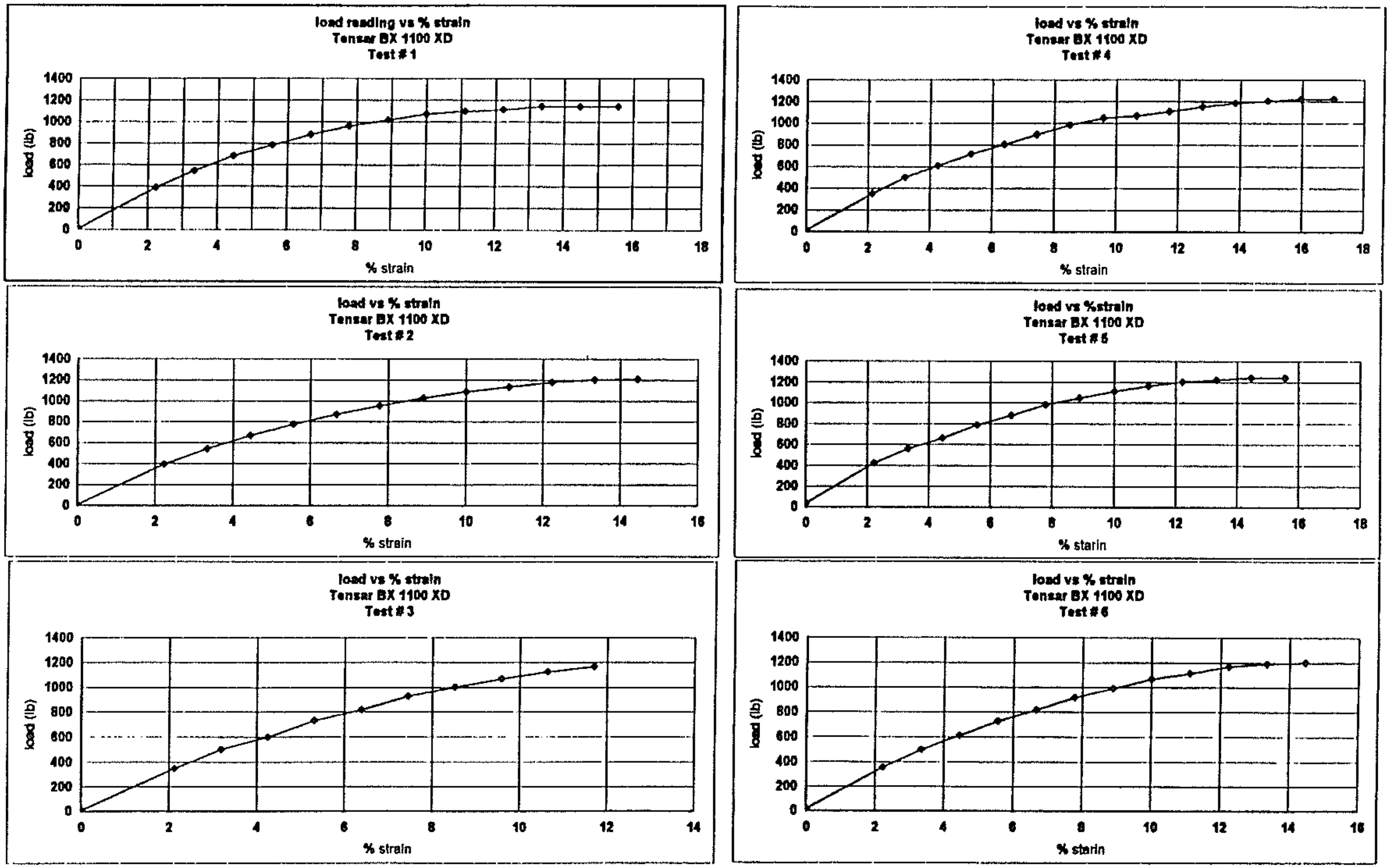

Figure C-2
Load vs. strain Tensar BX1100 cross direction

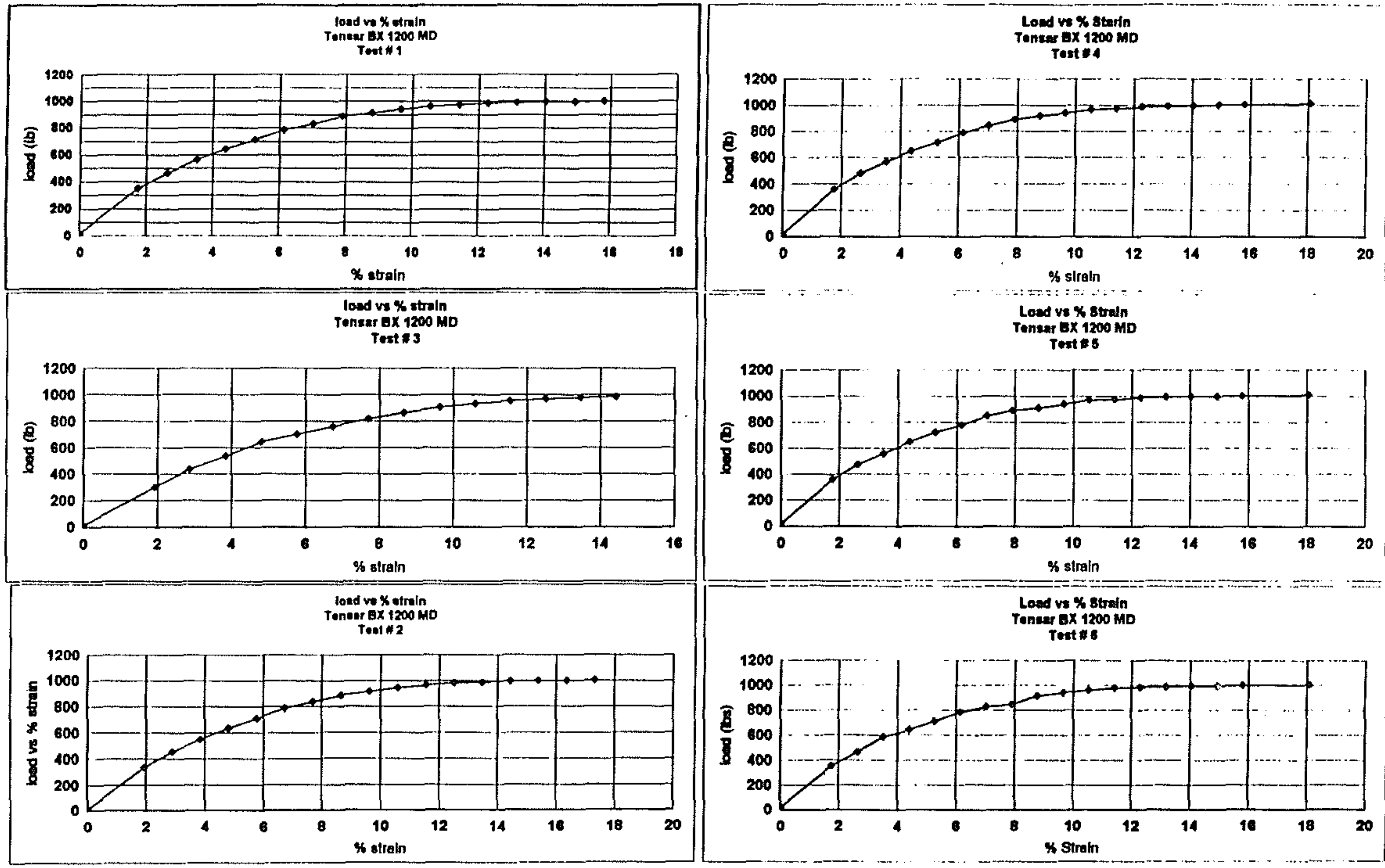

Figure C-3
Load vs. strain Tensar BX1200 machine direction

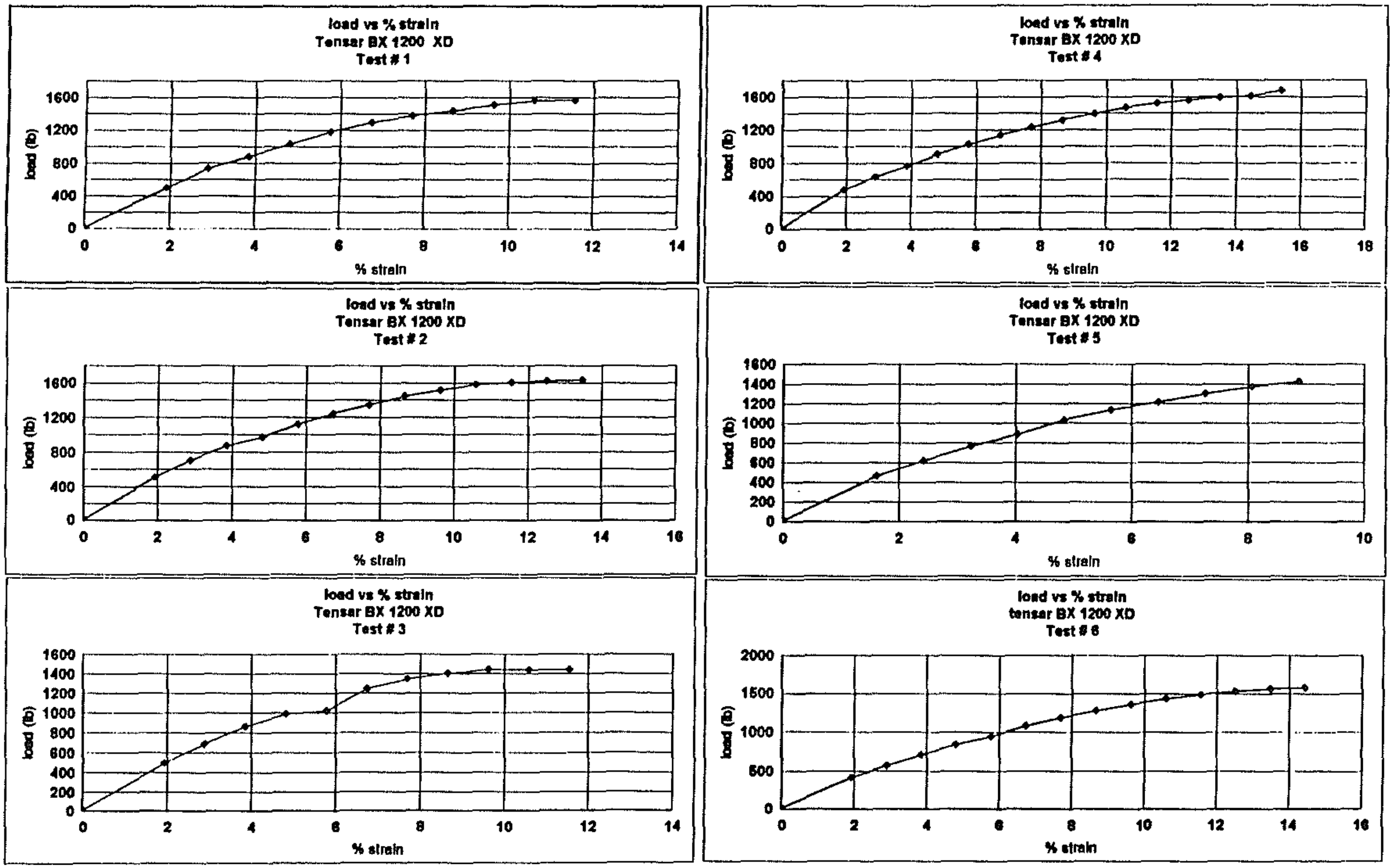

Figure C-4
Load vs. strain Tensar BX1200 cross direction

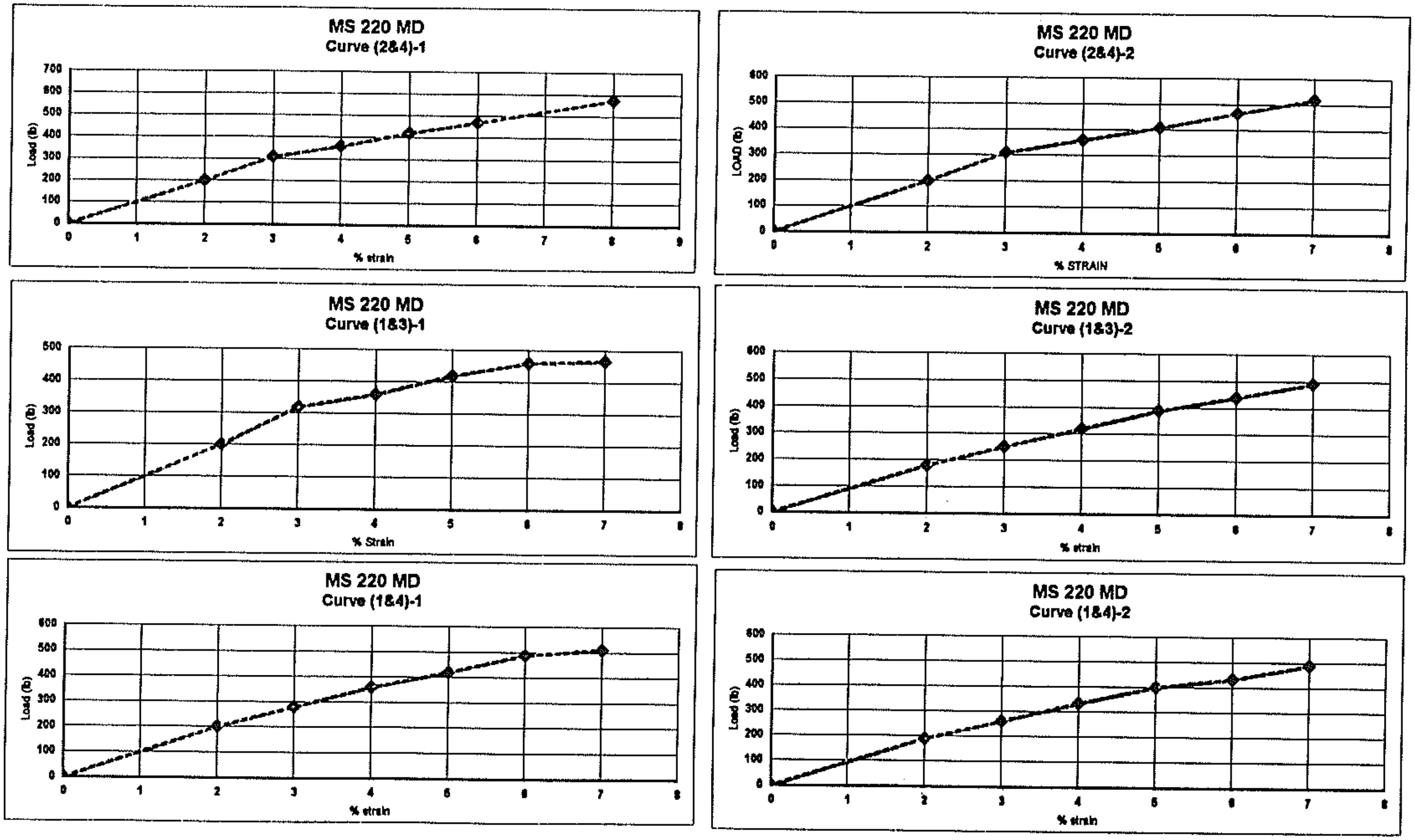

Figure C-5
Load vs. strain Tenax MS 220 machine direction

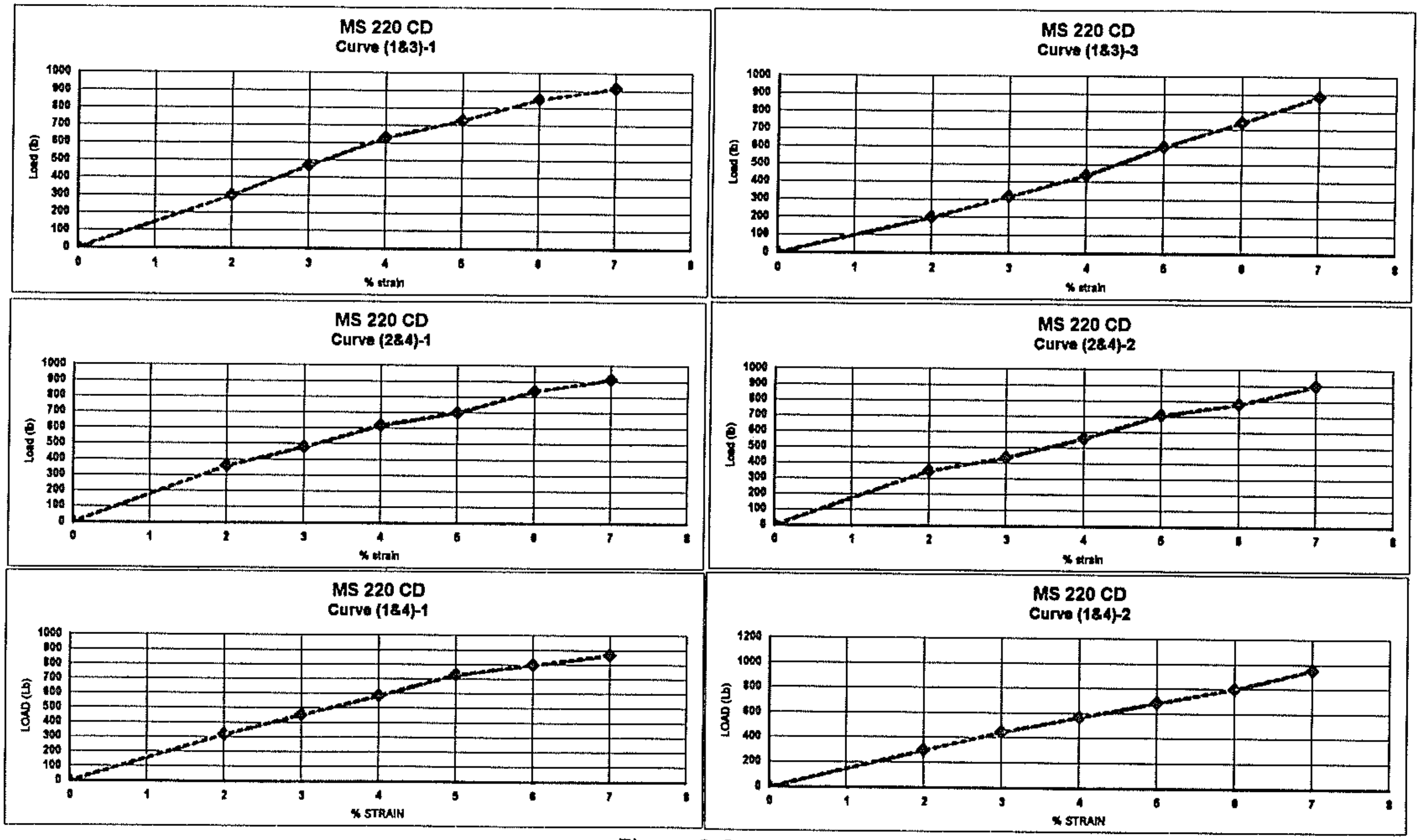

Figure C-6
Load vs. strain Tenax MS 220 cross direction

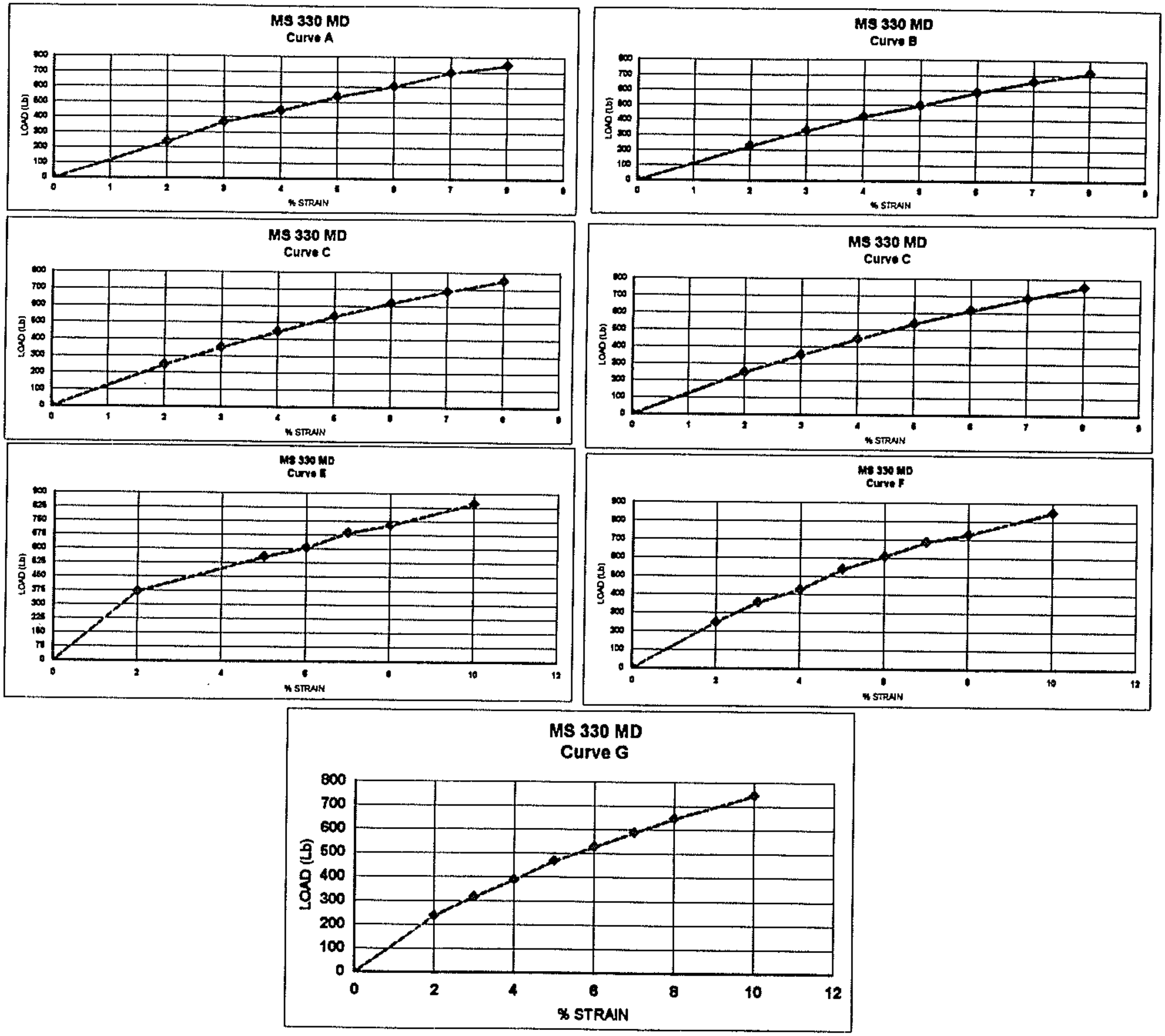

Figure C-7
Load vs. strain Tenax MS 330 machine direction

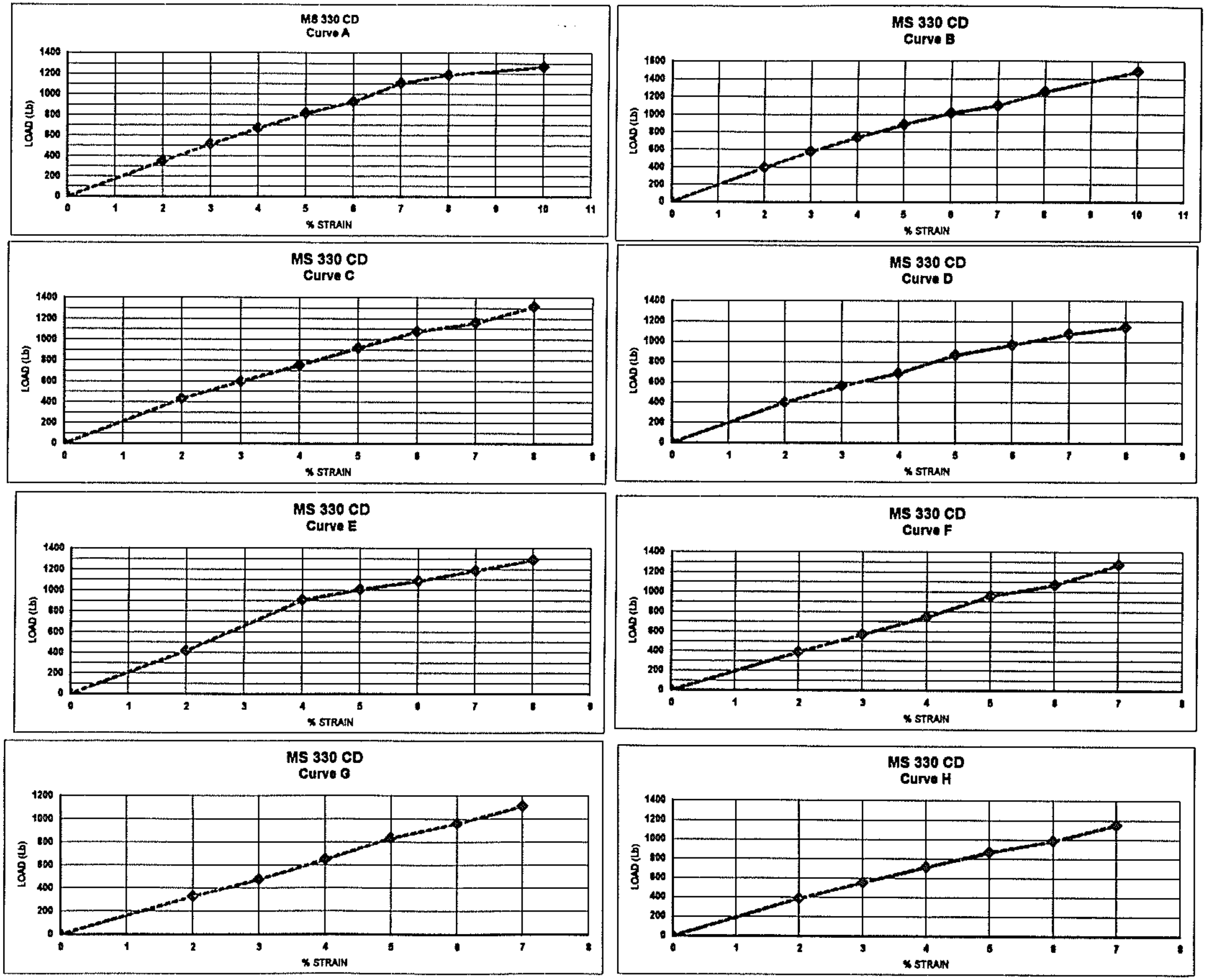

Figure C-8
Load vs. strain Tenax MS 330 cross direction

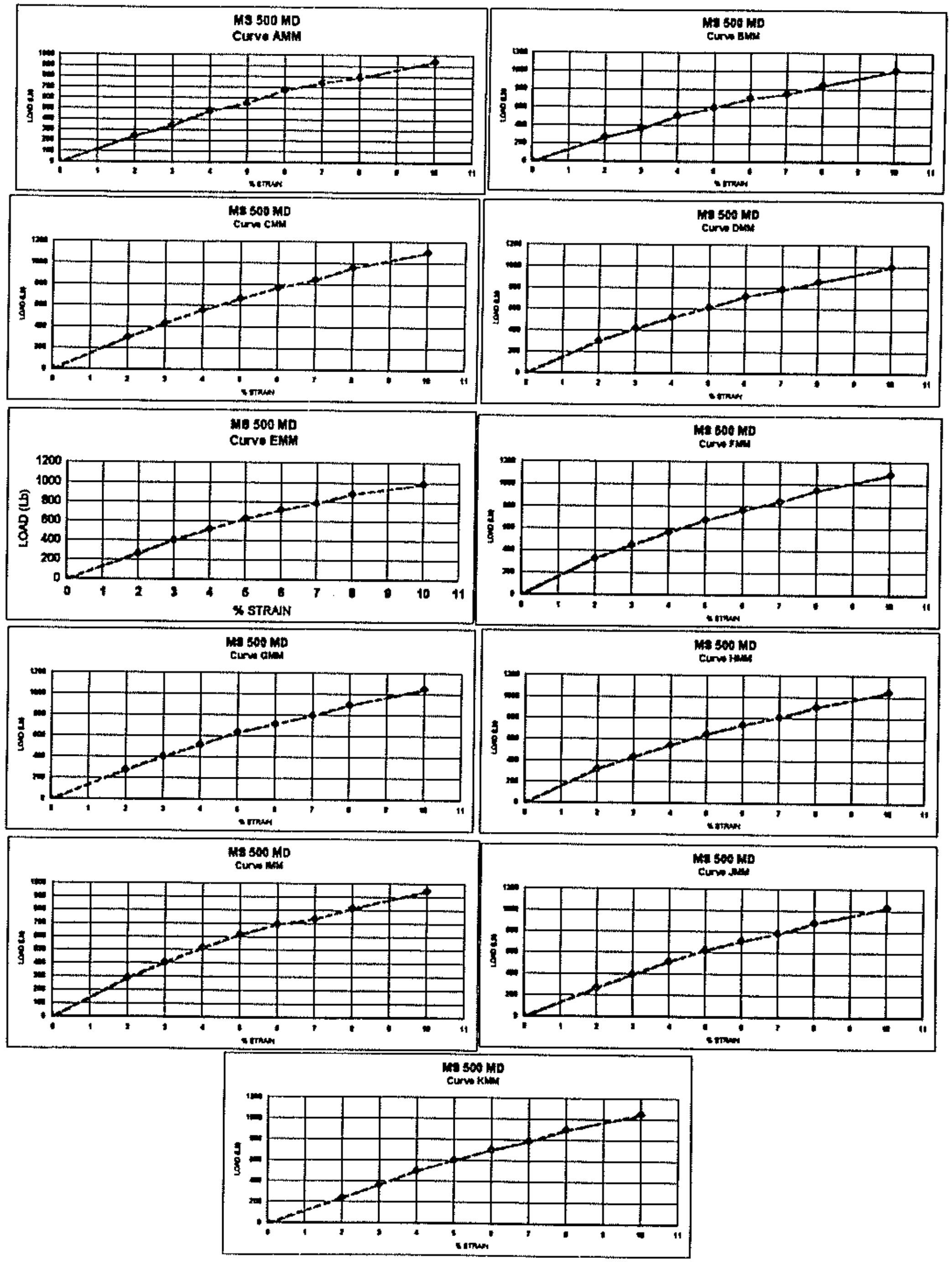

Figure C-9
Load vs. strain Tenax MS 500 machine direction

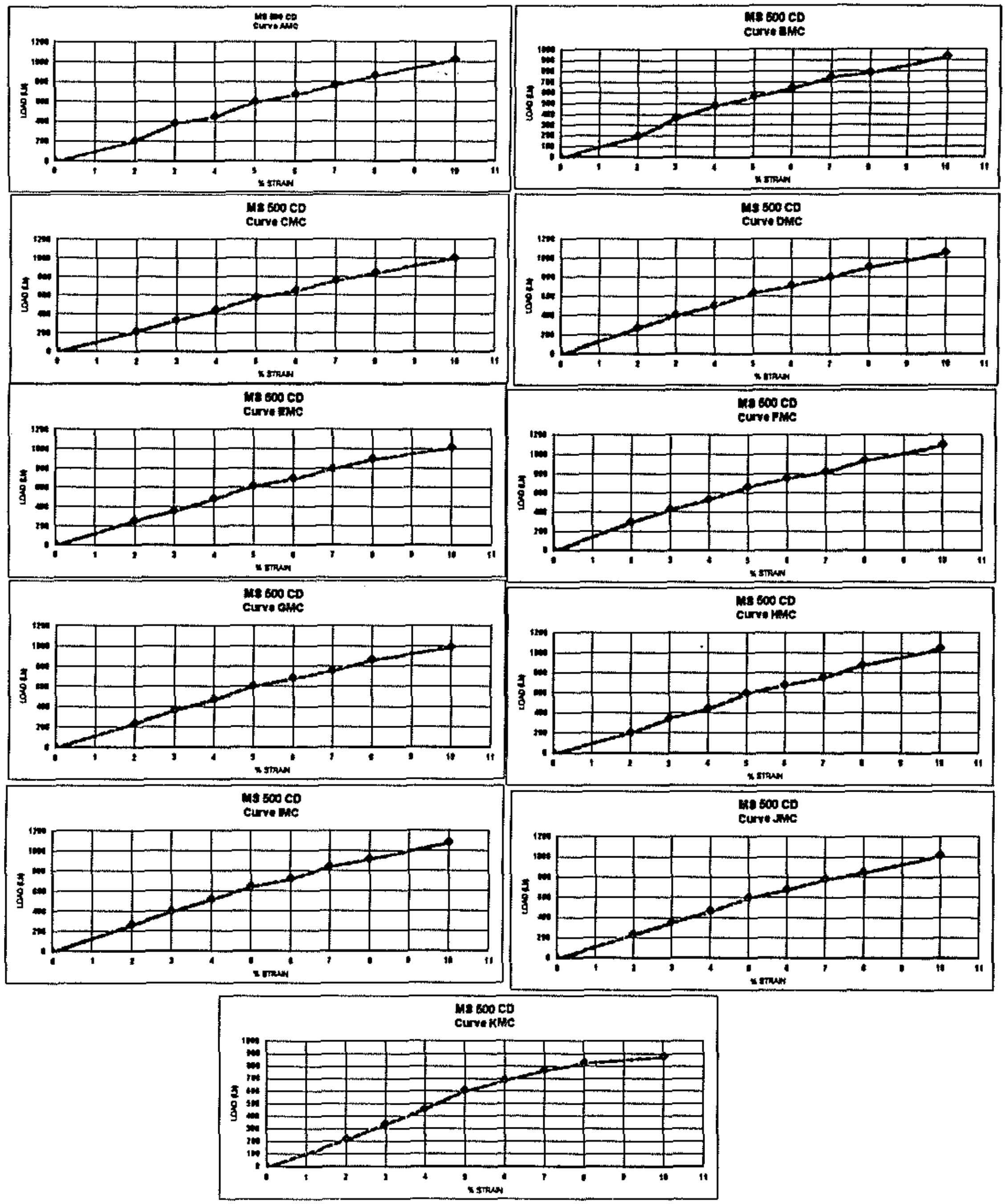

Figure C-10
Load vs. strain Tenax MS 500 cross direction

APPENDIX D

DOTD Construction Specifications on Geogrid

ITEM S-035, GEOGRID: This item consists of furnishing and placing geogrid reinforcement in the areas shown on the plans prior to placement of base course.

Materials:

(1) General Requirements: The geogrid shall be a biaxially oriented polymer grid structure composed of polypropylene or higher density polyethylene with apertures designed to interlock with the surrounding fill material. The joints at the crossover points of mesh itself, are to be construction activities or under dynamics loads anticipated over the life of the structure. The geogrid shall be resistant to damage during construction, including ultraviolet degradation, and it shall have long-term resistance to chemical and biological degradation caused by the materials being reinforced.

(2) Detailed Requirements:

Property	Test Method	Requirements
Aperture Size,	I.D. Calipered	1.0-2.0 in.
Open Area, min.	COE method	70%
Flexural Rigidity, min.	ASTM D1388-64	250,000 mg-cm
Tensile Modulus, min.	GRI GGI-87	14,000 lb/ft
Junction Efficiency, min.	GRI GG2-87	90%

NOTES:

1. All numerical values represent minimum average roll values required in the designated direction.

2. The contractor shall submit a Certificate of Compliance that the geogrid meets the physical properties outlined above. The Department reserves the right to randomly sample and test geogrid material.

Construction Methods

The goegrid shall be placed in continuous sheets parallel to the centerline. Adjacent sheets of grids shall be overlapped a minimum of 18 inches. Care shall be taken to ensure that sections do not separate during construction.

The grid shall be cut to conform to curved sections as to maintain parallel placement to centerline. Care shall be taken to ensure that excessive buckling of the grid material does not occur. Excess material quantity, if any, required for making curves shall be at no direct pay.

Tracked equipment will not be allowed to operate directly on the grid. Damaged fabric shall be either removed and replaced with new grid or covered with a second layer of grid extending three feet in each direction from the damaged area.

Each grid roll shall be labeled or tagged to provide product identification sufficient for field inventory and quality control purposes. Rolls shall be stored in a manner which protects them from the elements. If stored outdoors, they shall be elevated and protected from ultraviolet light.

Measurement and Pavement

Quantity of Geogrid Reinforcement will be paid by the square yard of covered area at the contract unit price under:

Item S-020, geogrid, per square yard.