Report No. CDOT-DTD-R-2005-01
Appendices A - H

EVALUATION OF THE FRP-RETROFITTED ARCHES IN THE CASTLEWOOD CANYON BRIDGE

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APPENDIX A. FIBRWRAP CONSTRUCTION DOCUMENTS

This appendix contains the drawings prepared by the engineers at Fyfe Co. for the Fibrwrap application scheme. The application process was comprised of three consecutive phases. Phase 1 included the longitudinal and transverse sheets between the arch-foundation connections and the first spandrel columns. In this region, more Fibrwrap was applied to the extrados than the intrados due to the large negative moments expected from a concentrated truck load above the second spandrel column. Sheet 4 of Phase 1 was part of a later addendum which addressed the reinforcing details around the arch struts.

The bulk of each arch was reinforced in Phase 2. The longitudinal Fibrwrap was applied first. This was approximately evenly distributed between the extrados and the intrados. The arch ribs, except for the area pertaining to Phase 3, were then covered with alternate full and C-shaped wraps. The full wraps on either side of the spandrel columns were doubled to provide extra confinement around the column-arch connections. Sheet 8 of Phase 2 was part of the subsequent strut addendum. When Phase 2 was completed, the arch ribs were considered strong enough to withstand the construction loads associated with the replacement of the columns and deck.

Phase 3 was undertaken after the existing spandrel columns were removed. The column footprints were covered with transverse Fibrwrap. The struts were also wrapped with alternating full and C-shaped wraps.

A few ambiguities were clarified by personal communication with the engineers at Fyfe Co.. Unless noted otherwise, longitudinal and transverse Fibrwrap strips are 12” wide. The thickness of one layer is 0.04”.

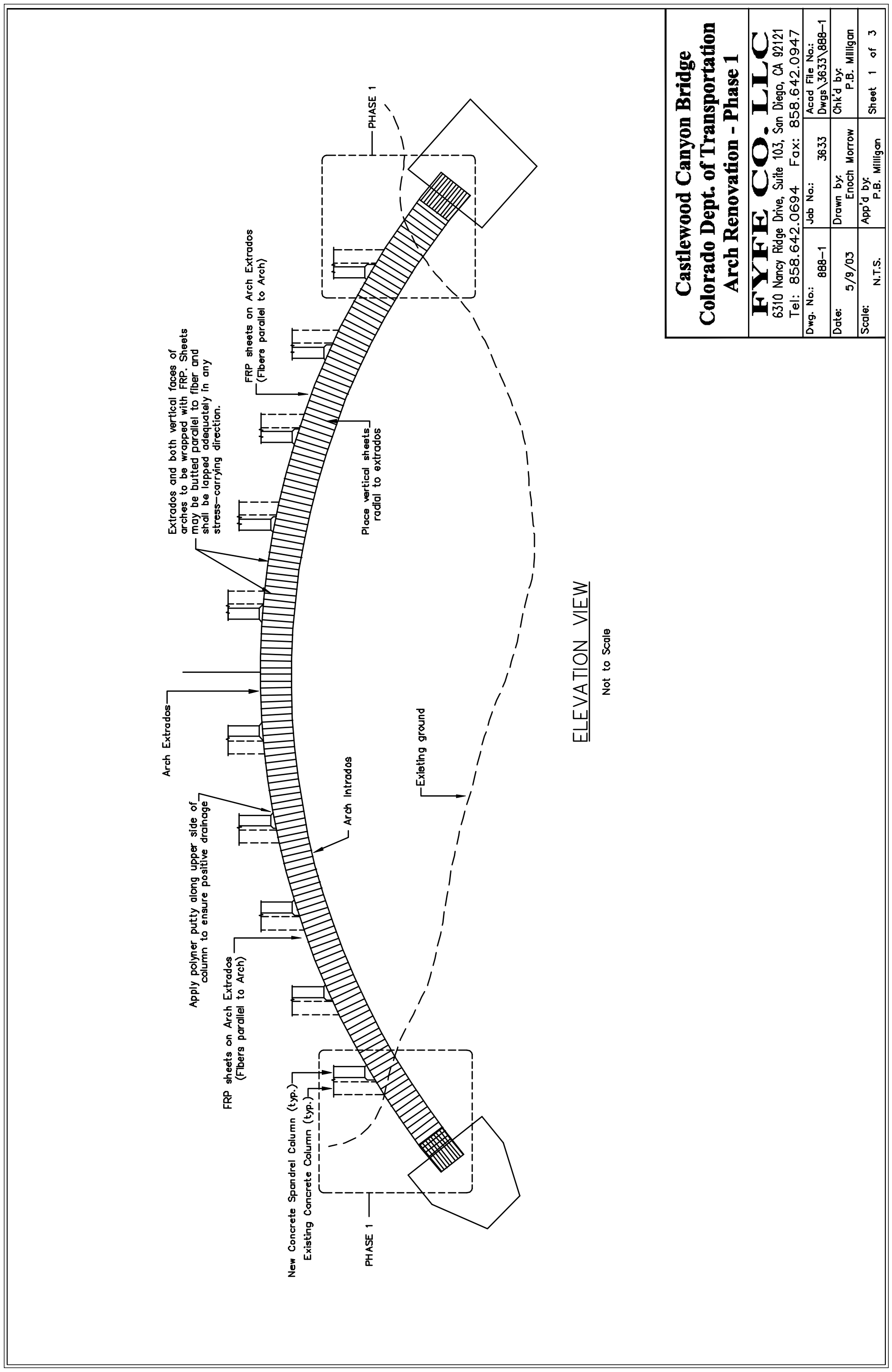


Figure A-1 Fibrwrap Phase 1: Sheet 1 of 4

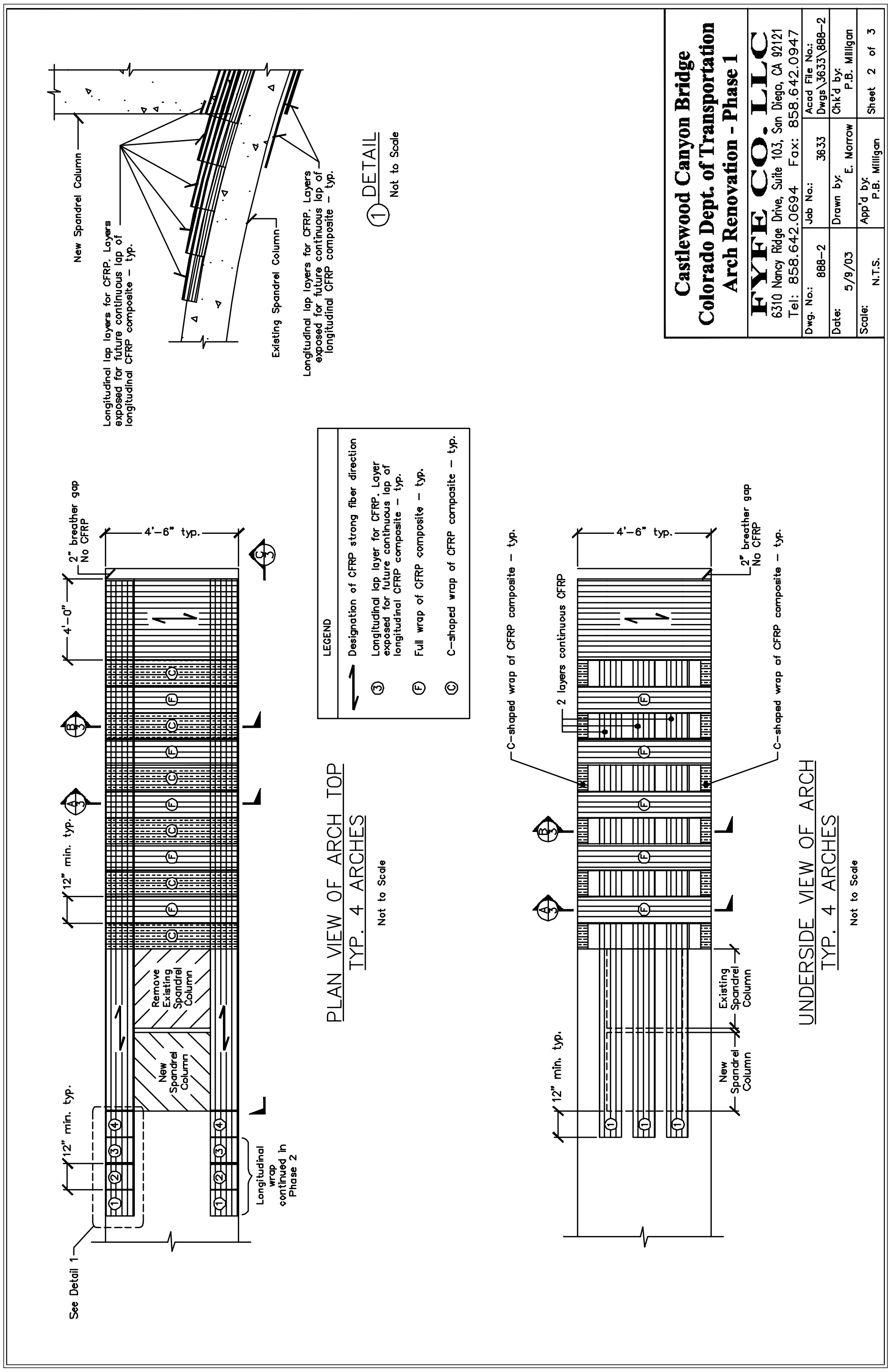


Figure A-2 Fibrwrap Phase 1: Sheet 2 of 4

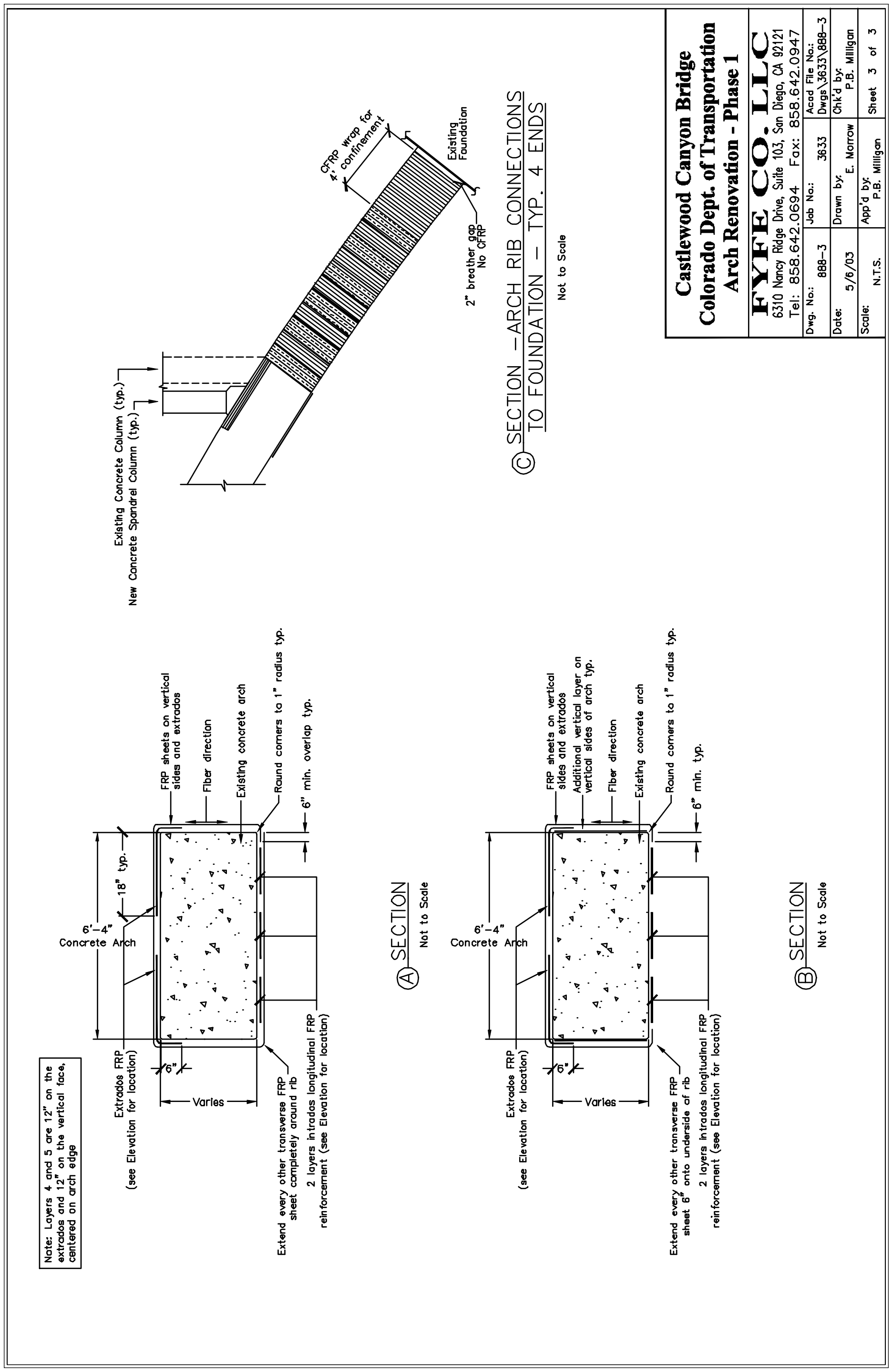


Figure A-3 Fibrwrap Phase 1: Sheet 3 of 4

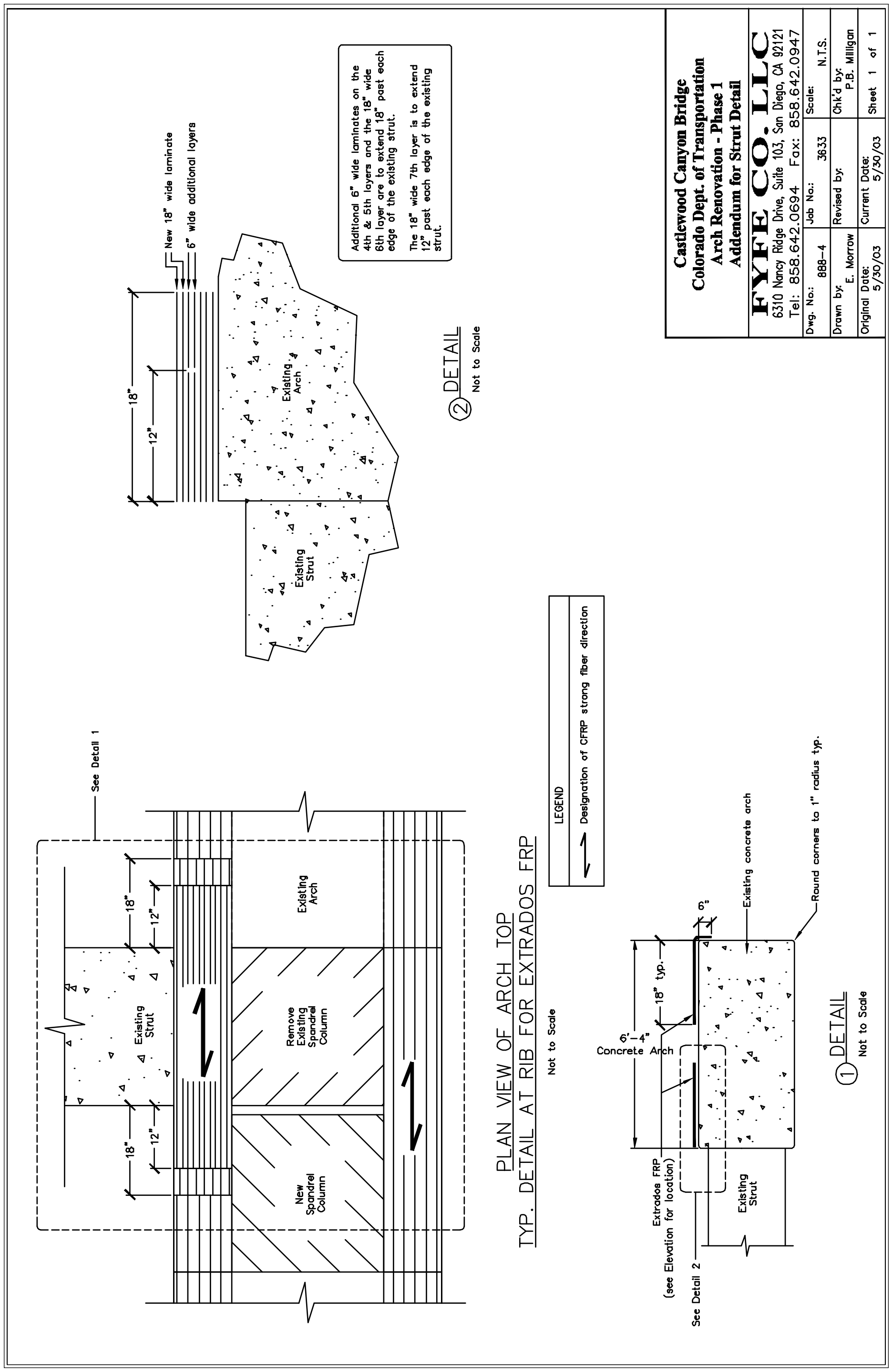


Figure A-4 Fibrwrap Phase 1: Sheet 4 of 4

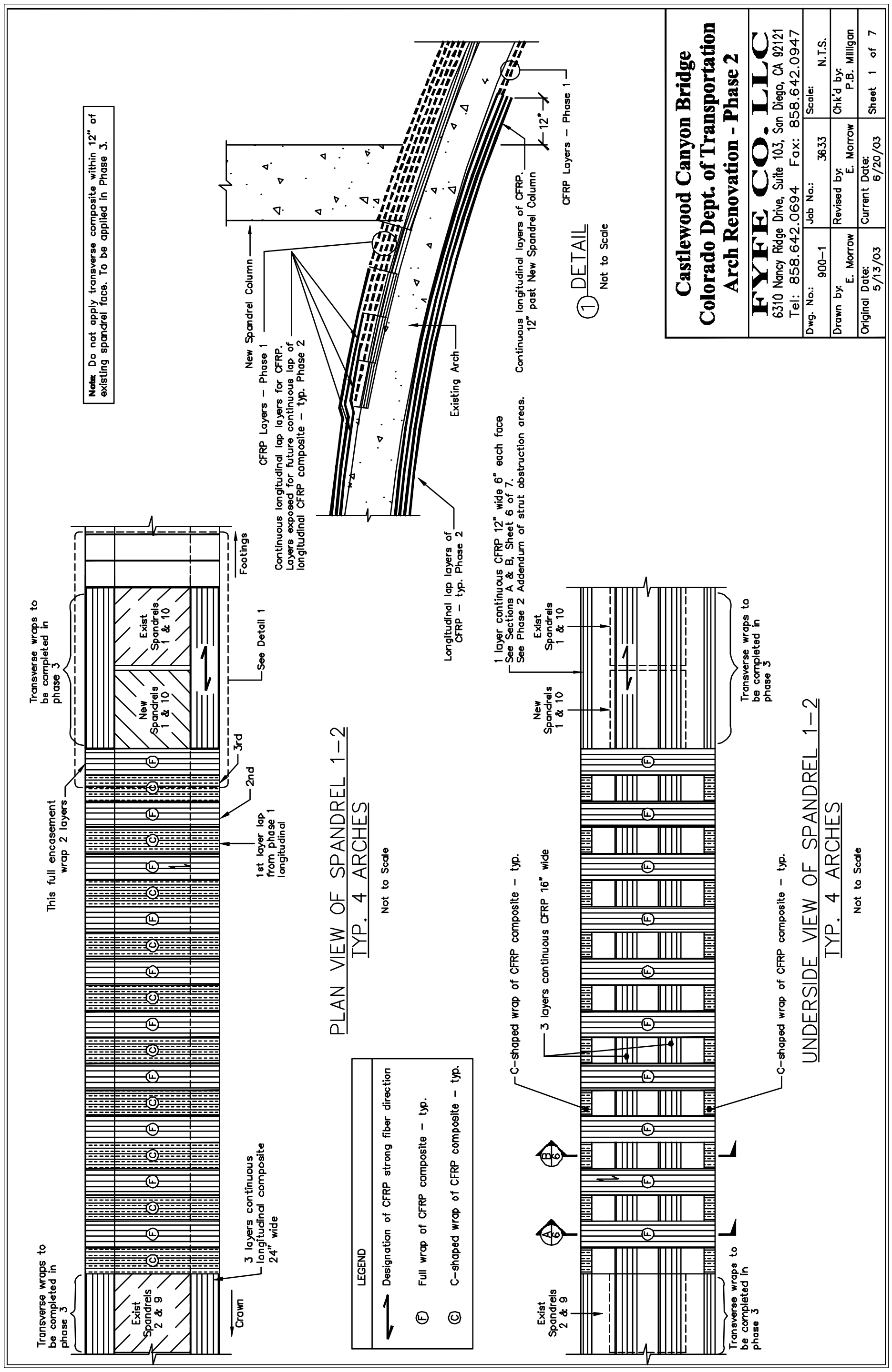


Figure A-5 Fibrwrap Phase 2: Sheet 1 of 8

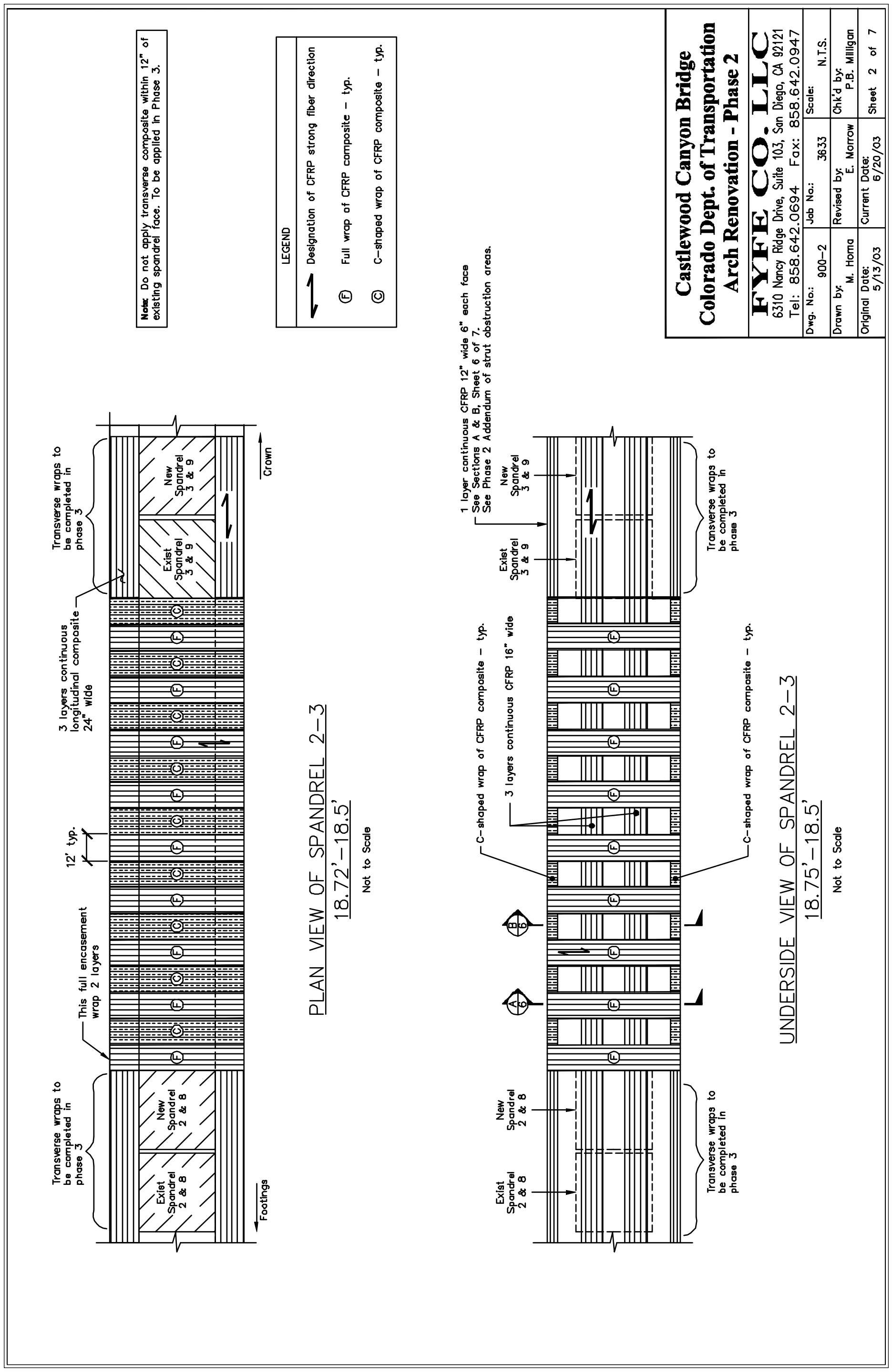


Figure A-6 Fibrwrap Phase 2: Sheet 2 of 8

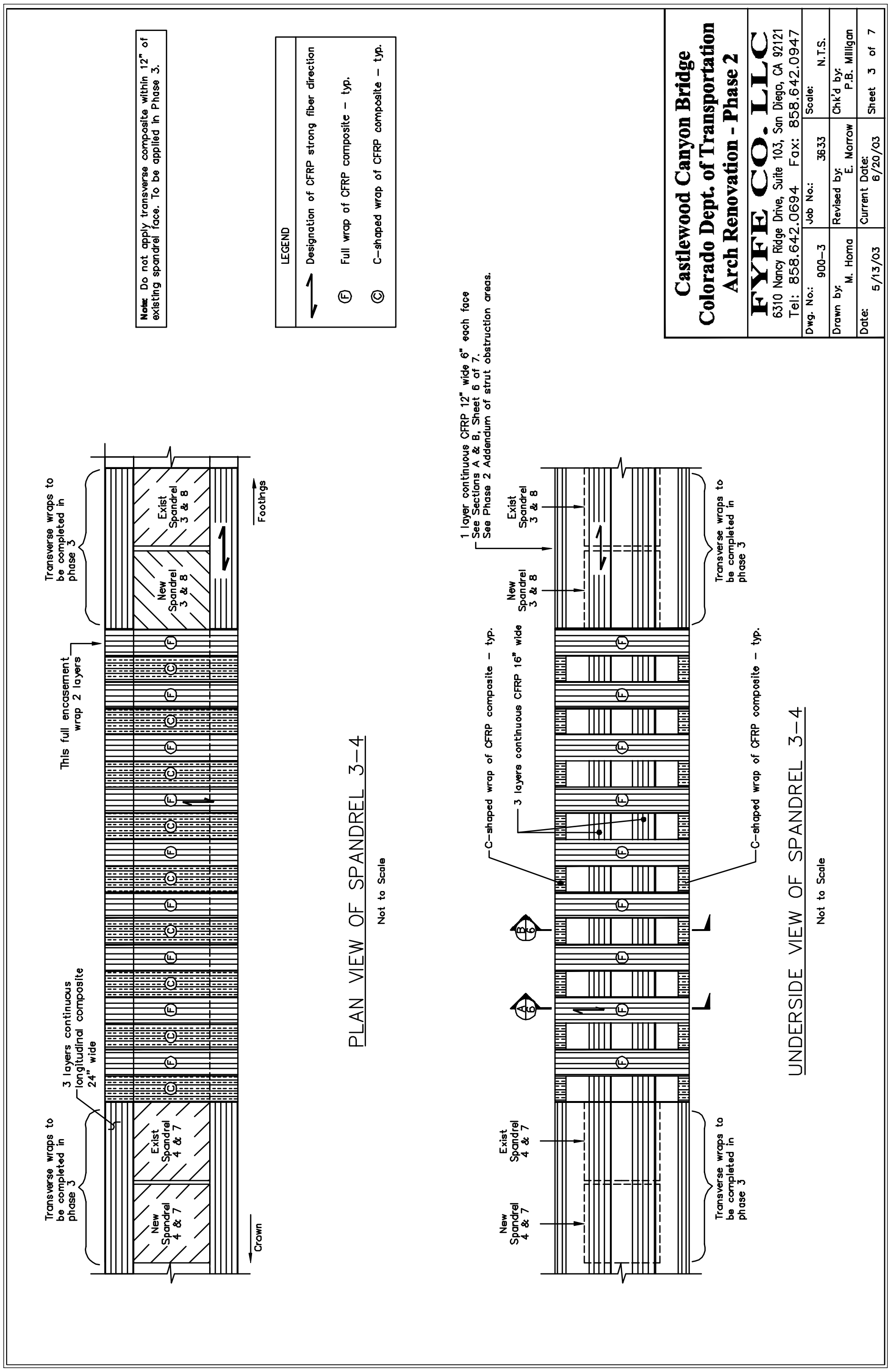


Figure A-7 Fibrwrap Phase 2: Sheet 3 of 8

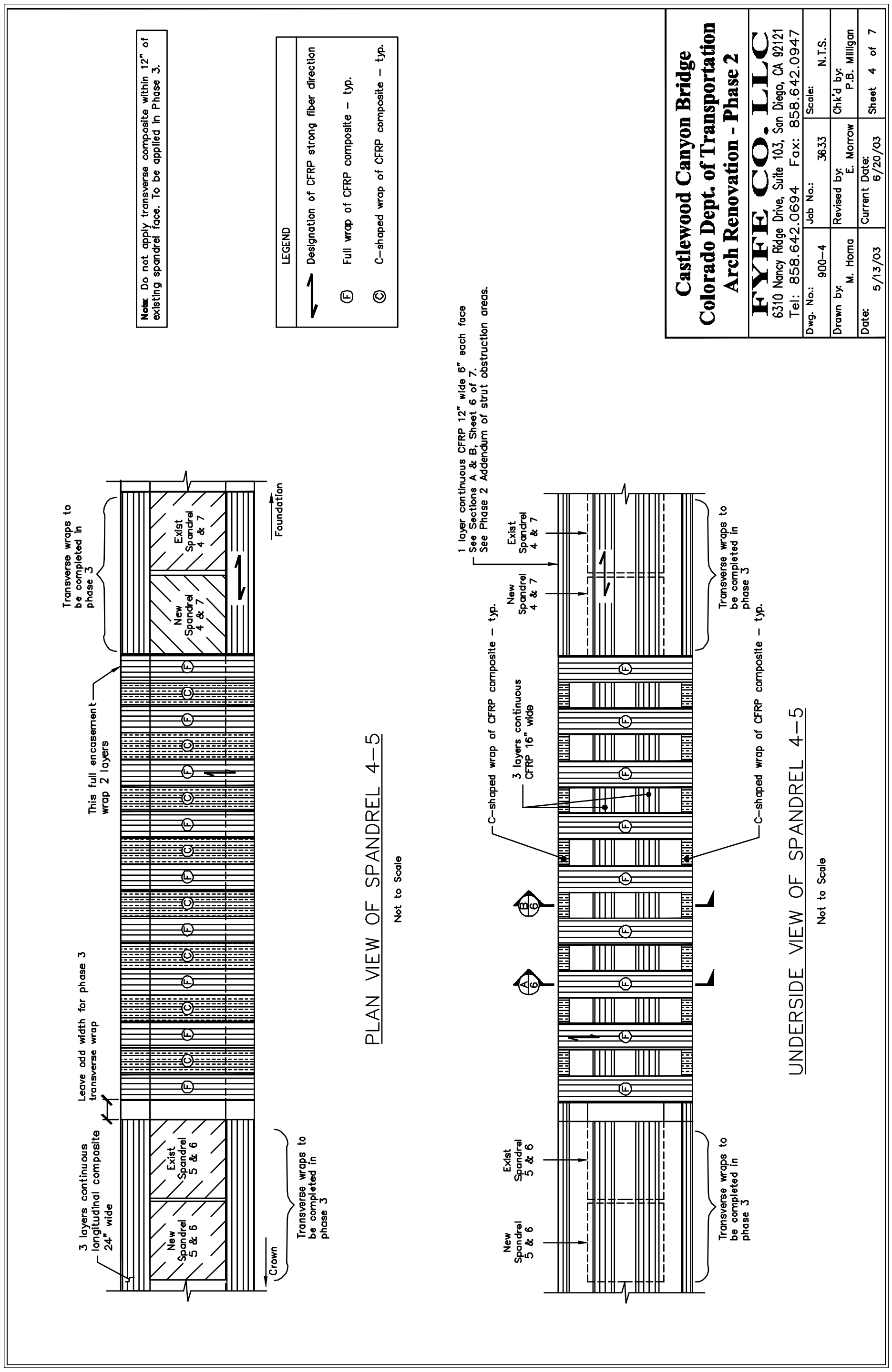


Figure A-8 Fibrwrap Phase 2: Sheet 4 of 8

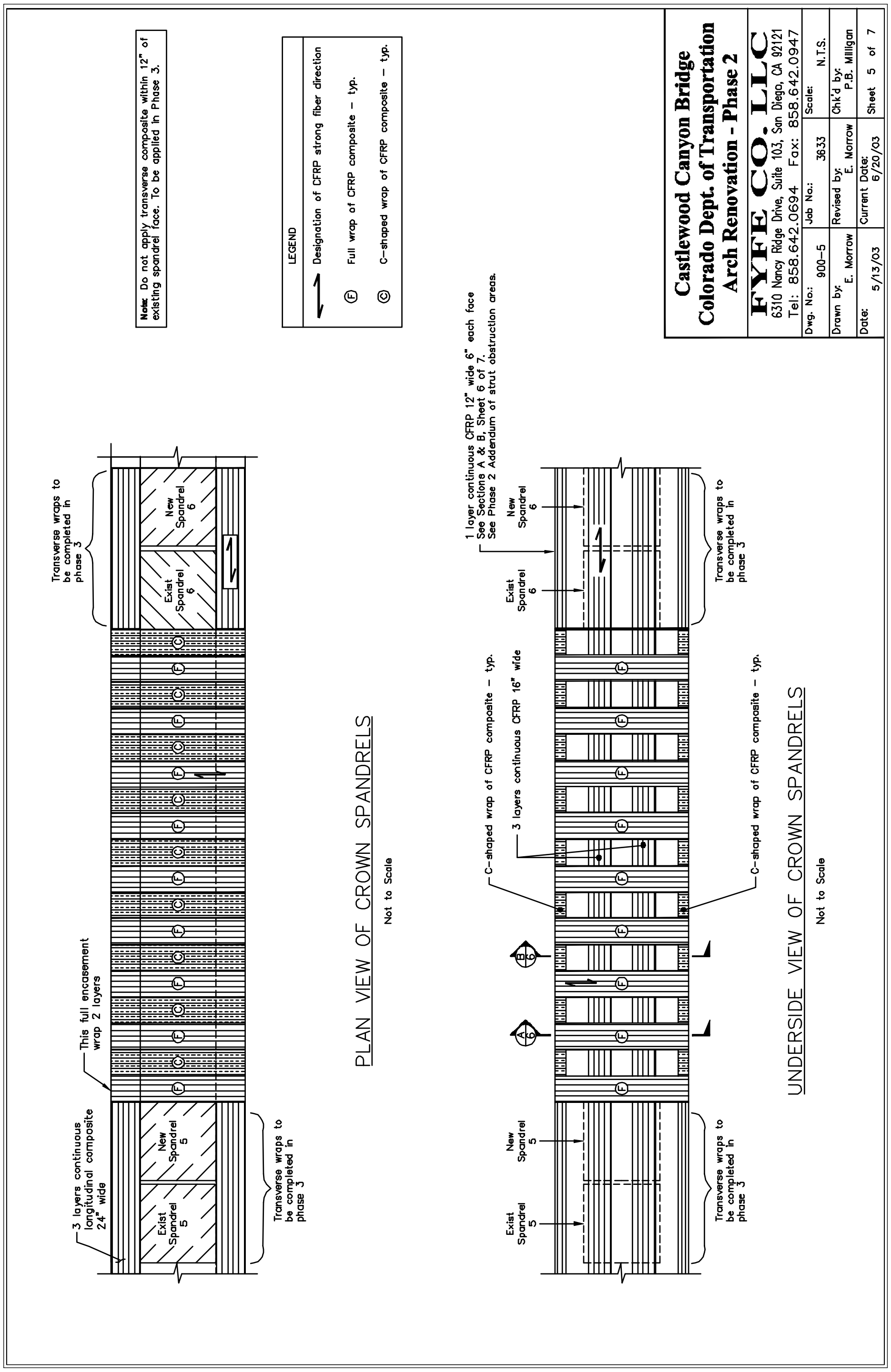


Figure A-9 Fibrwrap Phase 2: Sheet 5 of 8

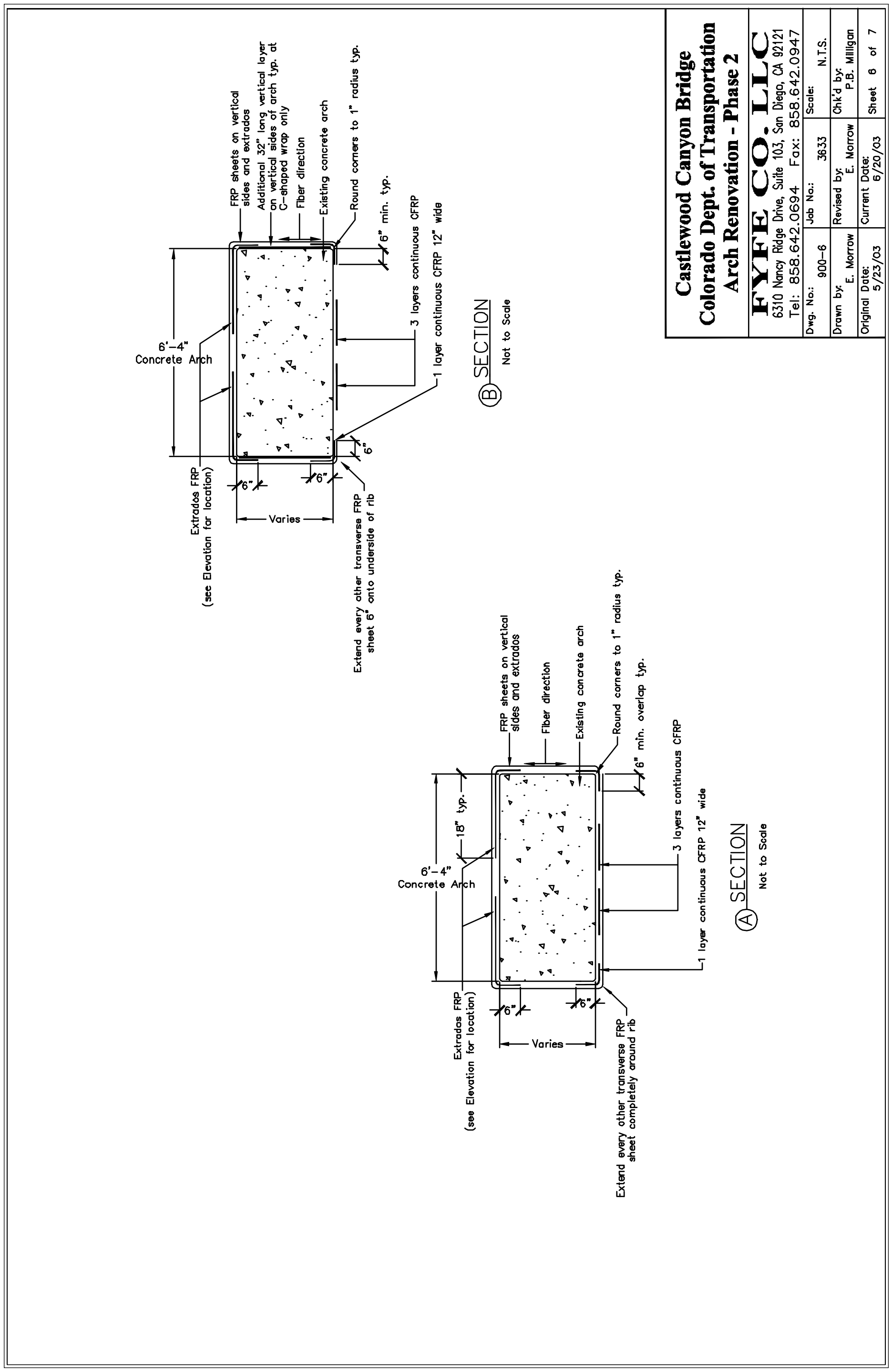


Figure A-10 Fibrwrap Phase 2: Sheet 6 of 8

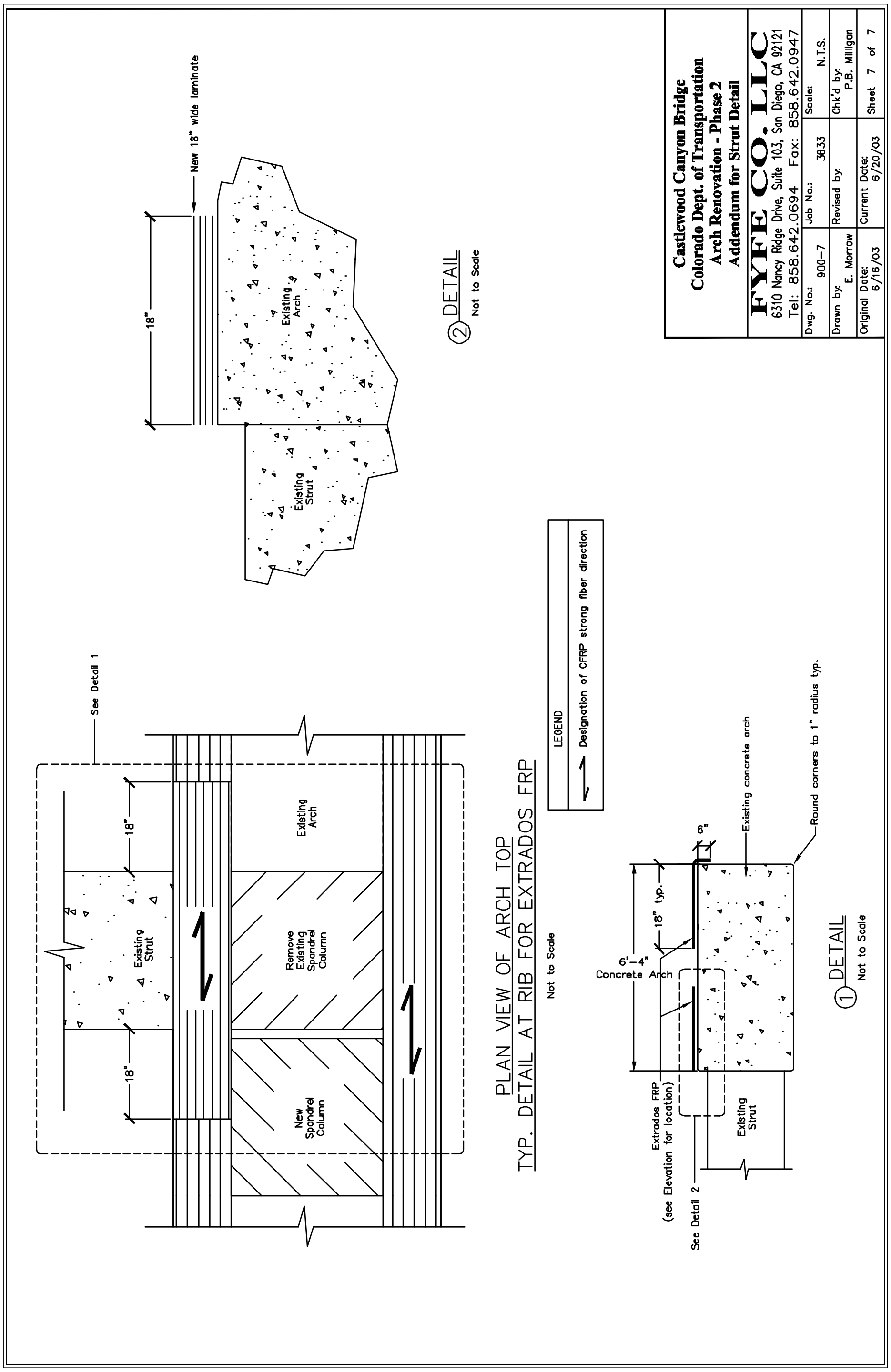


Figure A-11 Fibrwrap Phase 2: Sheet 7 of 8

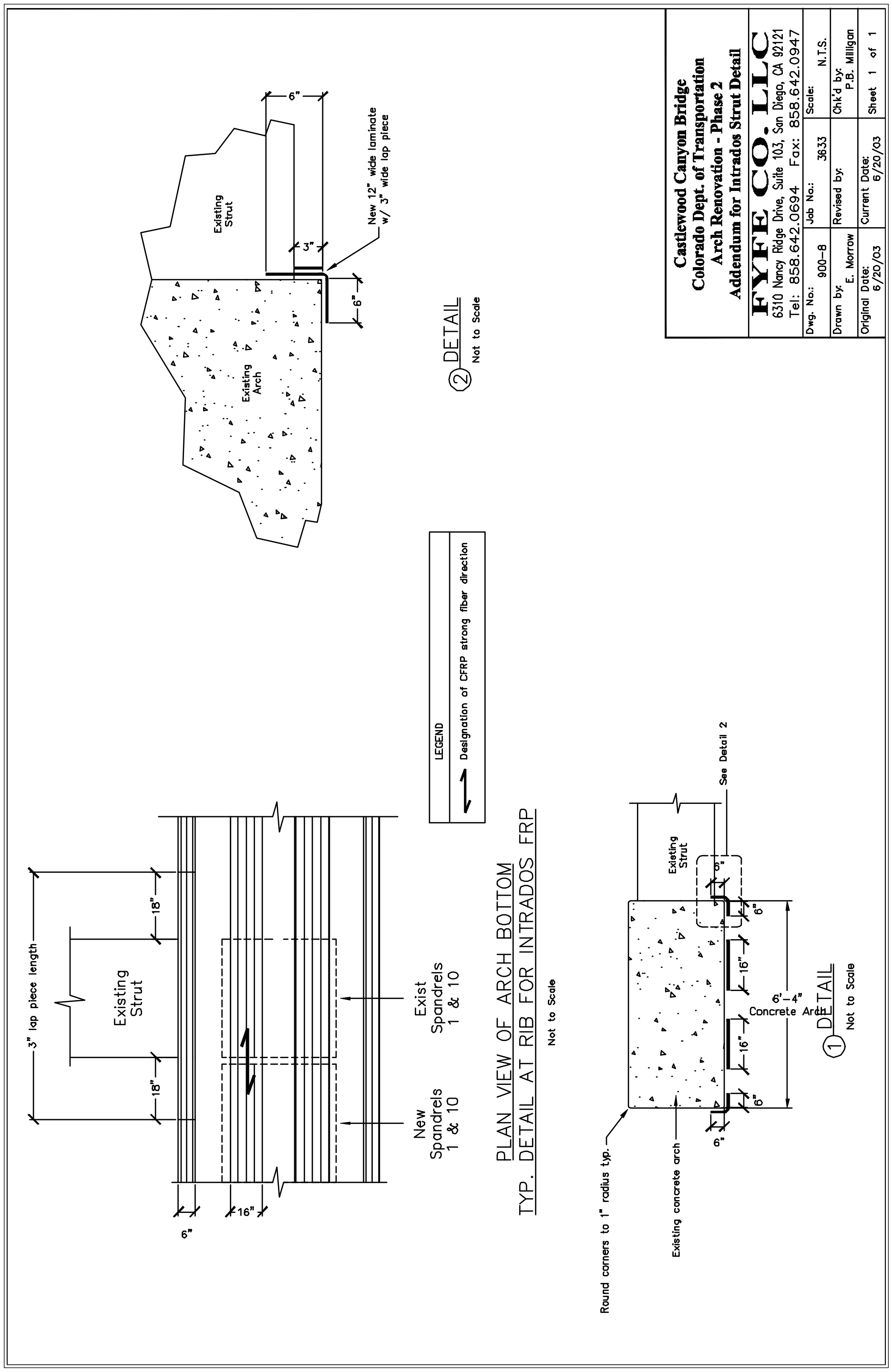


Figure A-12 Fibrwrap Phase 2: Sheet 8 of 8

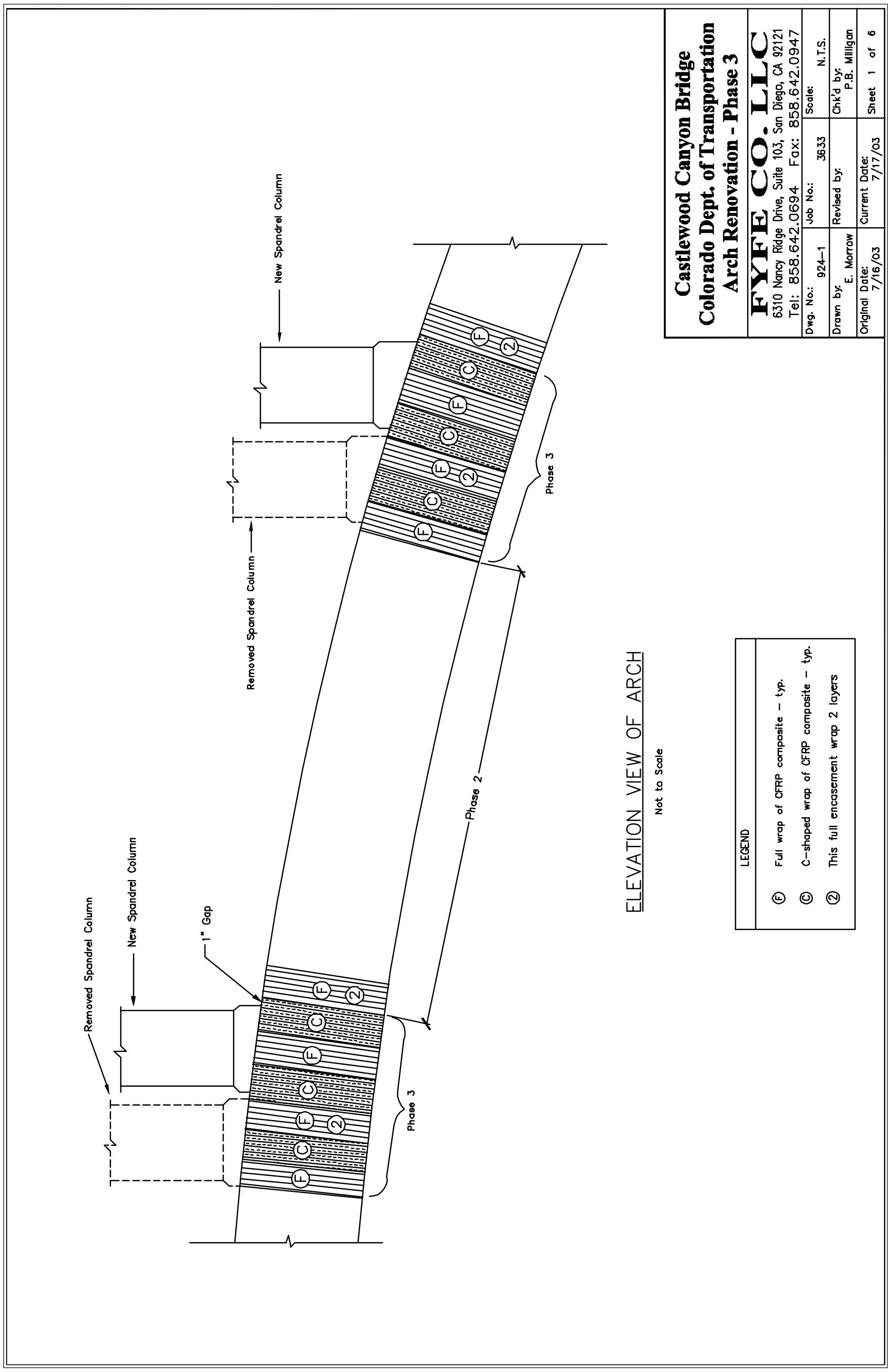


Figure A-13 Fibrwrap Phase 3: Sheet 1 of 6

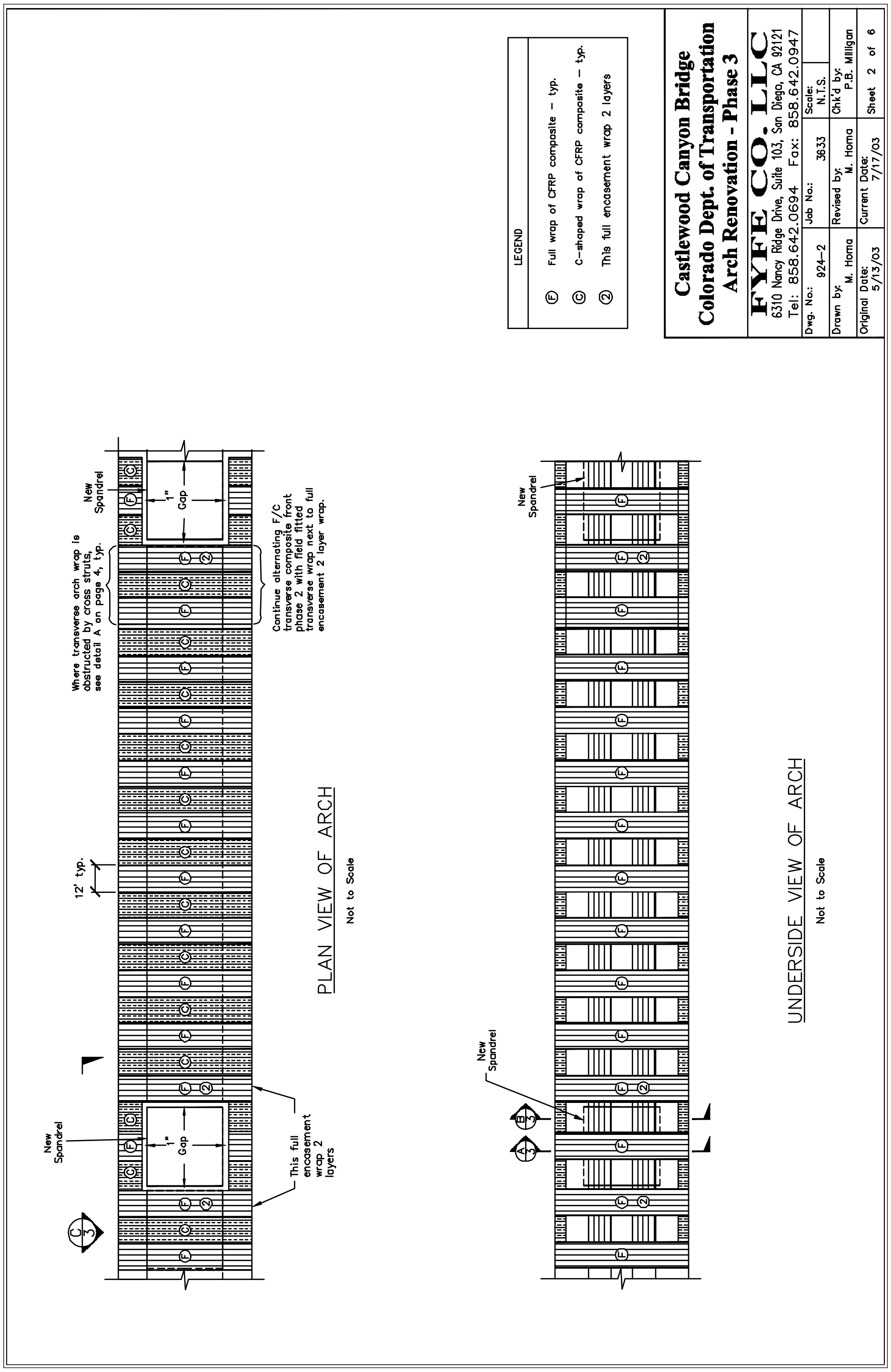


Figure A-14 Fibrwrap Phase 3: Sheet 2 of 6

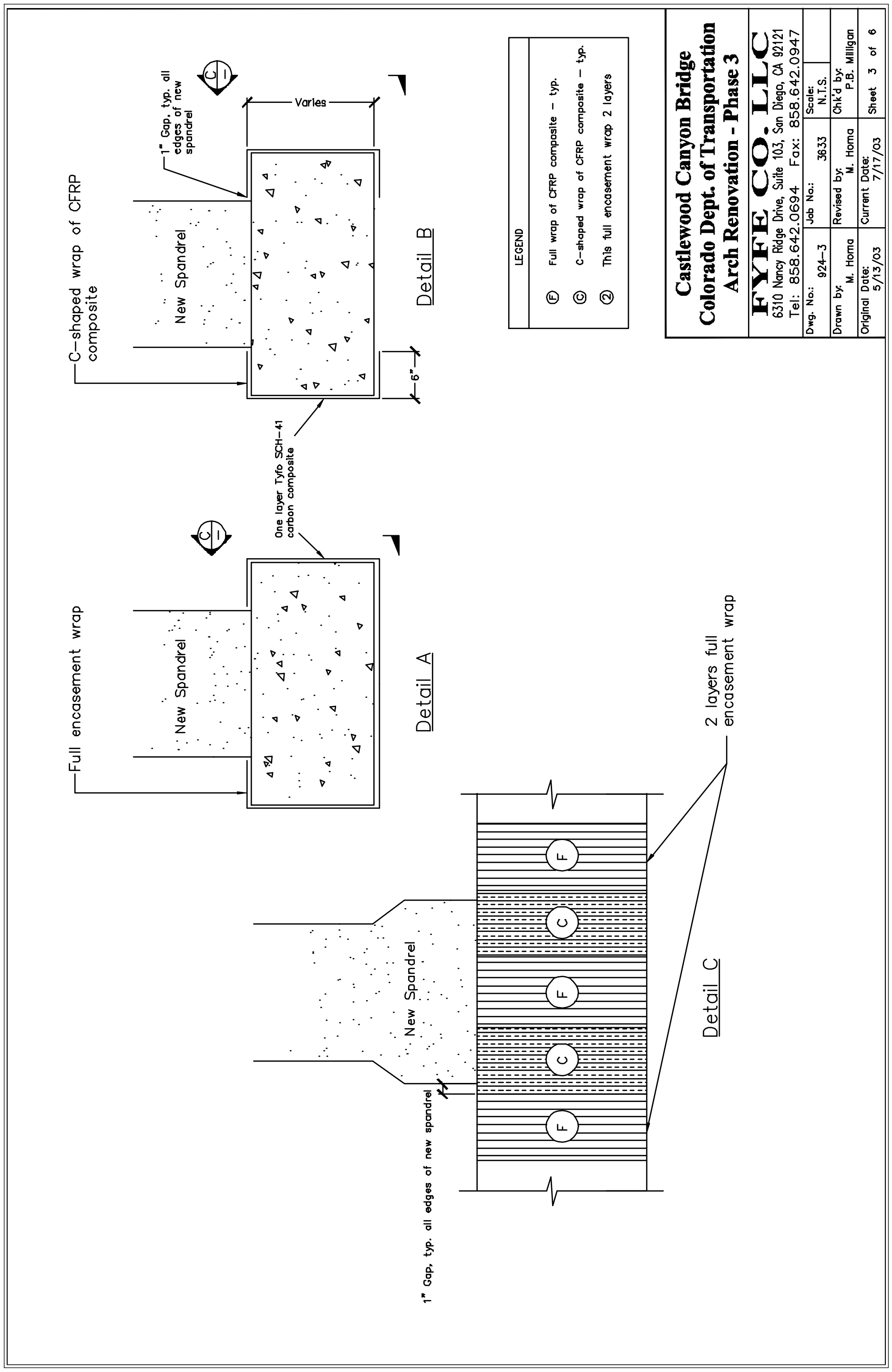


Figure A-15 Fibrwrap Phase 3: Sheet 3 of 6

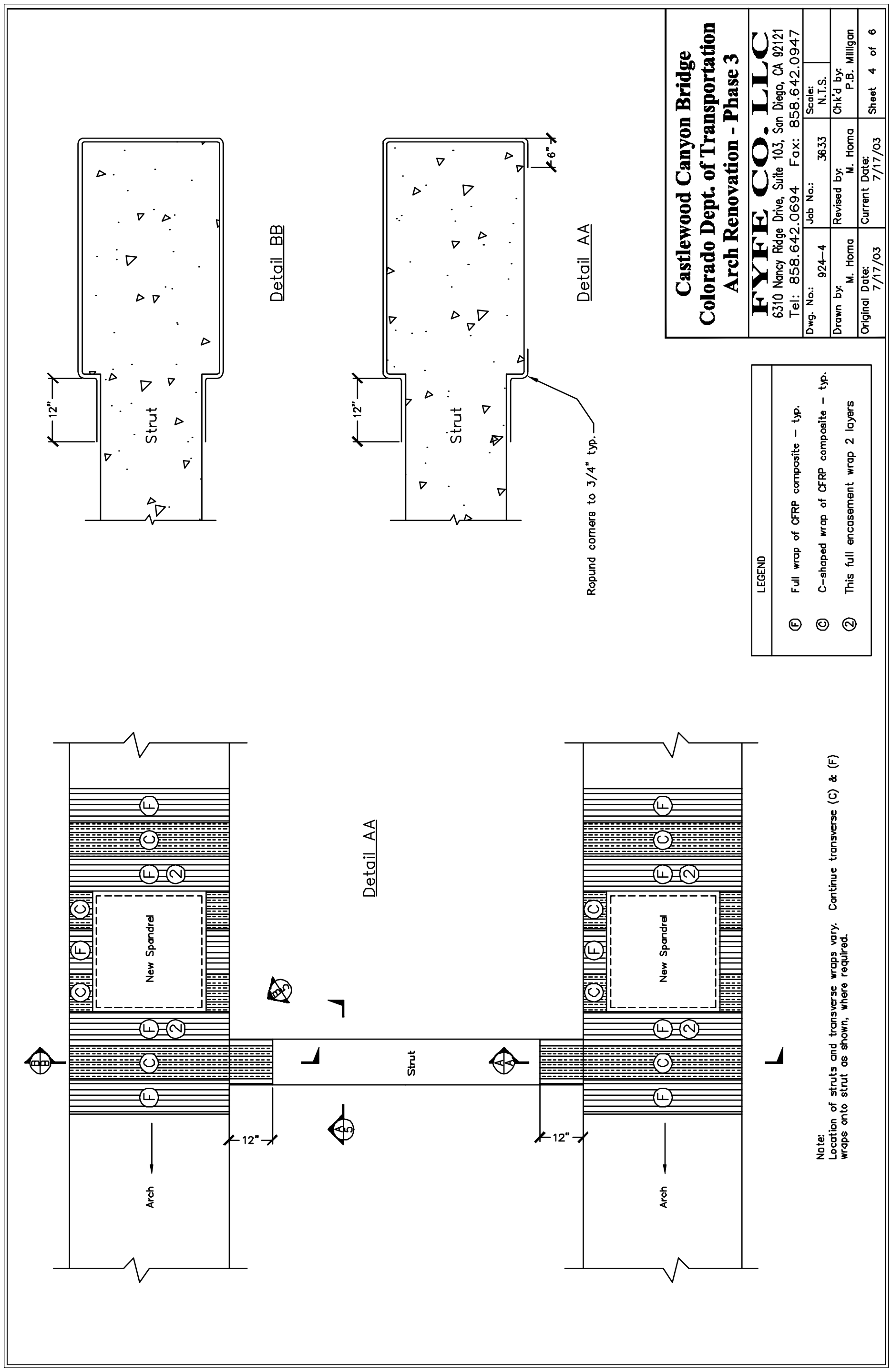


Figure A-16 Fibrwrap Phase 3: Sheet 4 of 6

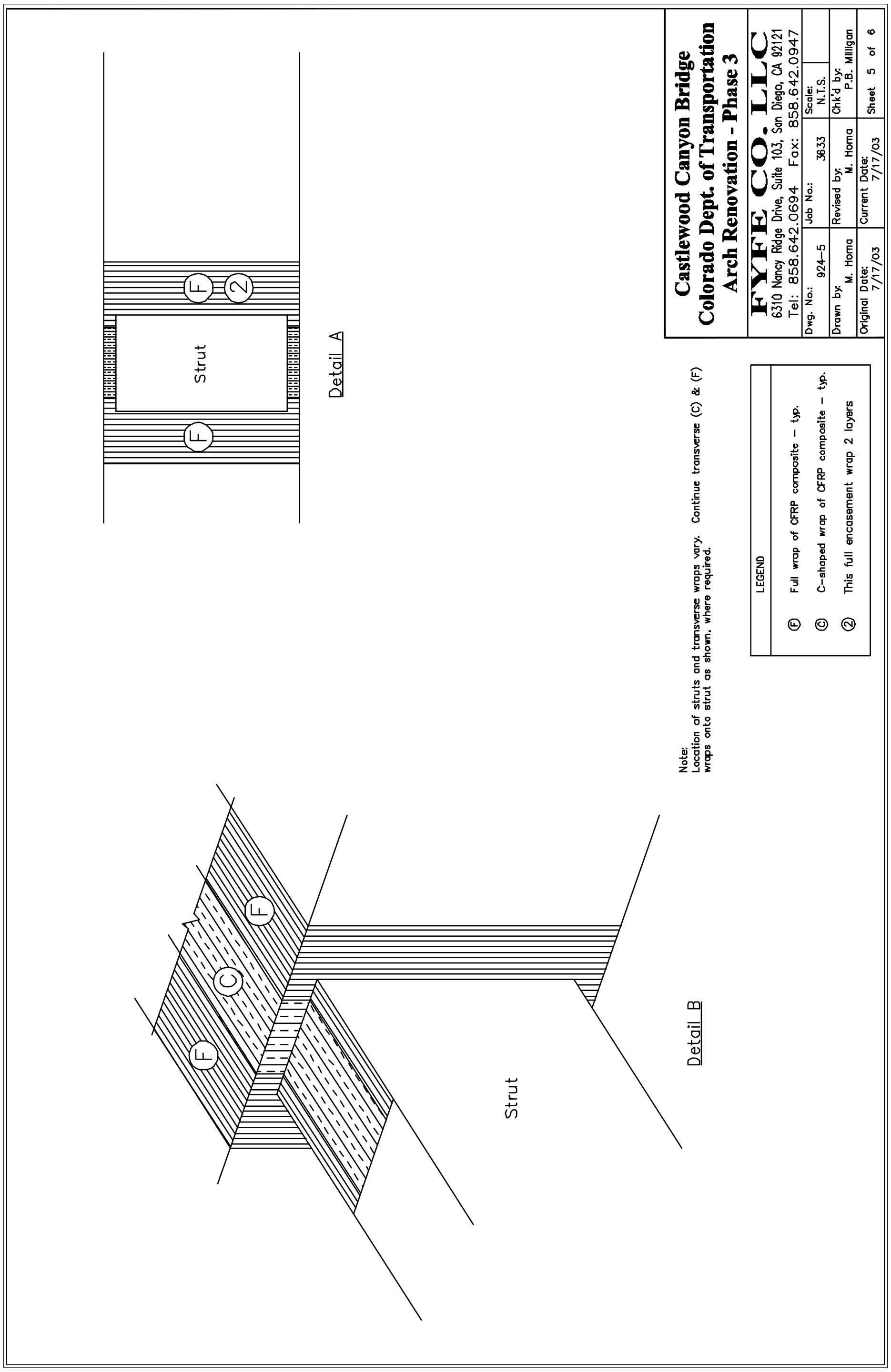


Figure A-17 Fibrwrap Phase 3: Sheet 5 of 6

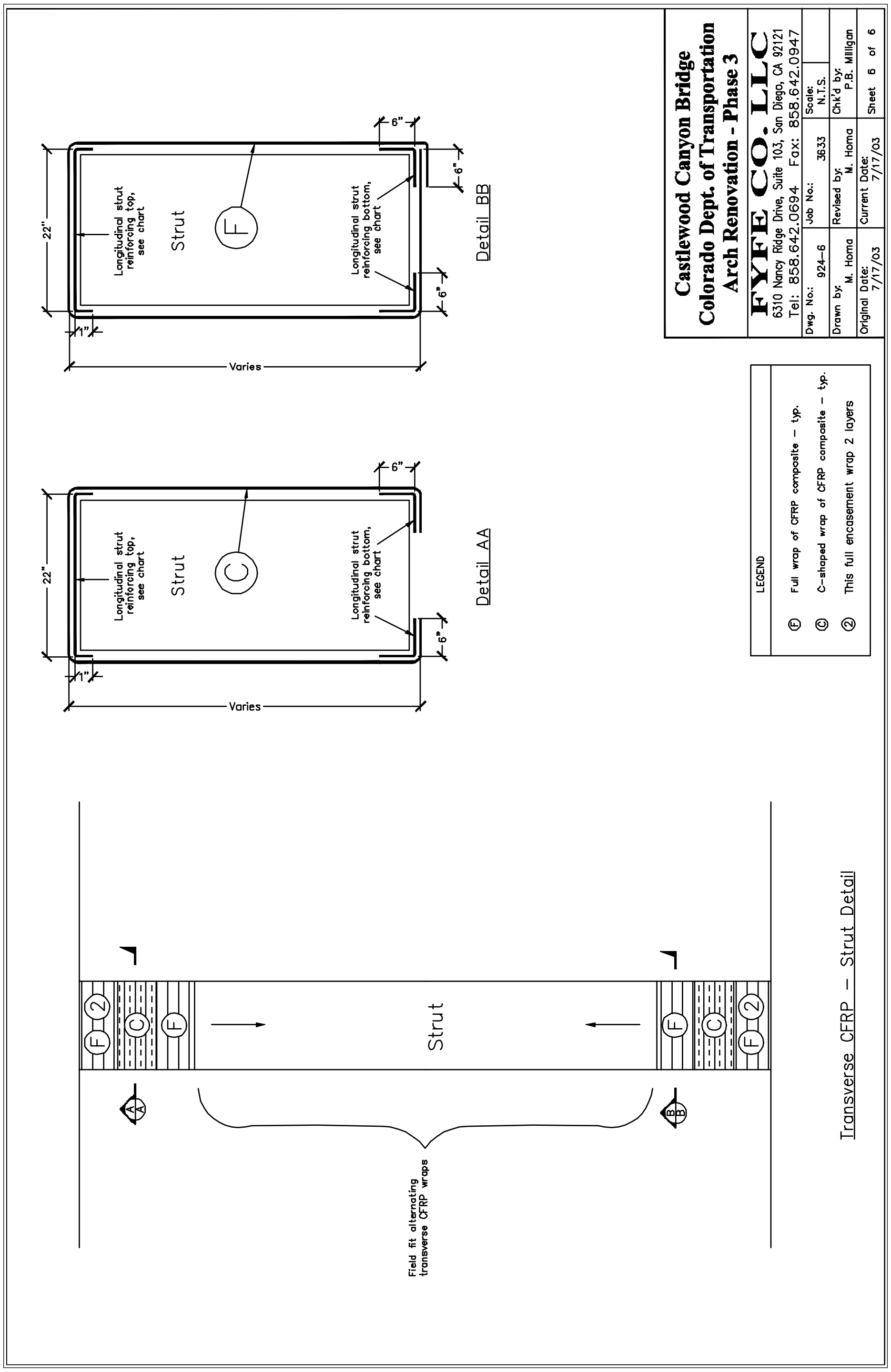


Figure A-18 Fibrwrap Phase 3: Sheet 6 of 6

APPENDIX B. ANALYSIS OF TEST SPECIMENS

Foundation Retrofitted Specimen Analysis

Geometry

The geometry and concrete regions of the FR specimen before and after FRP hoop rupture are shown in Figure B-1. In (a), the thickness of the perimeter region of unconfined concrete is equal to one quarter of the clear spacing between the FRP hoops, or 0.75”. The centerlines of the steel hoops, shown in Section 1.4, were located approximately 1.75” within the top and bottom faces of the beam and 1.13” within sides of the beam. They were spaced at 8” on center. Thus, the boundary of the effectively confined steel core was placed a distance of 8”/4 = 2” within the centerline of the steel hoops. The clear spacing between the steel hoops was considered to be equal to their center-to-center spacing due to their small diameter. In (b), the FRP hoops have ruptured. All concrete not effectively confined by the steel hoops is considered to be unconfined.

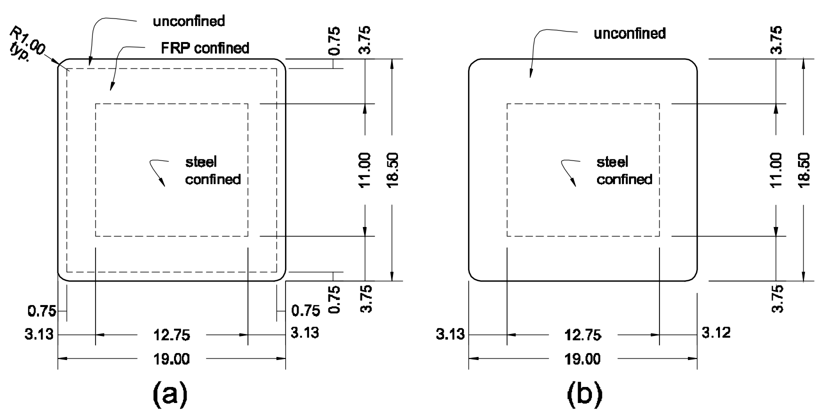


Figure B-1 FR section dimensions and concrete regions: (a) before FRP hoop rupture; (b) after FRP hoop rupture

Steel locations and areas:

@ 2.5” from beam bottom:	A_s = 0.8 in^2
@ 4” from beam bottom:	A_s = 0.91 in^2
@ 7.5” from beam bottom:	A_s = 0.4 in^2
@ 11” from beam bottom:	A_s = 0.4 in^2
@ 14.5” from beam bottom:	A_s = 0.91 in^2
@ 16” from beam bottom:	A_s = 0.8 in^2

The Fibrwrap on the FR specimen was not included in the section because it was terminated 1” away from the central block of the specimen.

Leadline locations and areas:

@ 1.5” from beam bottom:	A_{LL} = 0.2337 in^2
@ 9.25” from beam bottom:	A_{LL} = 0.1558 in^2
@ 17” from beam bottom:	A_{LL} = 0.2337 in^2

Shotcrete areas:

shotcrete depth @ beam bottom:	d_{shot} = 2 in
shotcrete depth @ beam top:	d_{shot} = 3 in

(Only 2” of shotcrete were specified at the top and bottom of the beam. However in an effort to increase the bond between the shotcrete and the concrete, depressions were left in the concrete between the steel hoops. These were then filled with the shotcrete. This increased the shotcrete depth by up to 1” in some placed. Thus, the effective depth of the shotcrete was considered to be 3” instead of 2” on the top of the specimen.)

Material Properties

Concrete:

cylinder compressive strength	f'_{co} = 2.88 ksi
Young’s modulus	E = 3092 ksi

Shotcrete:

cylinder compressive strength	f'_{co} = 3.4 ksi
Young’s modulus	E = 3360 ksi

Steel:

longitudinal steel yield strength	f_y = 64.1 ksi
transverse steel yield strength	f_y = 40 ksi

Young's modulus	$E = 29000$ ksi
Fibrwrap:	
compressive rupture strain	$\varepsilon_{c,rup} = -0.002$
Young's modulus	$E = 10500$ ksi
Leadline:	
tensile strength	$f_u = 205$ ksi
compressive rupture strain	$\varepsilon_{c,rup} = -0.002$
Young's modulus	$E = 21320$ ksi

Relations for Concrete

Unconfined concrete (Kent and Park):	
strain at spalling	$\varepsilon_{sp} = 0.0063$
descending stress-strain slope	$Z = 188$ ksi
Steel confined concrete (Mander el al.):	
hoop spacing	$s_s = 8$"
width of core	$b_{core} = 16.5$"
height of core	$h_{core} = 14.75$"
area of transverse steel in x direction	$A_{ts,x} = 0.22$ in^2
area of transverse steel in y direction	$A_{ts,y} = 0.22$ in^2
density of trans. steel in x direction	$\rho_x = 0.0019$
density of trans. steel in x direction	$\rho_y = 0.0017$
cross sectional confined core area	$A_{cc} = 239$ in^2
effectively confined core area	$A_e = 133$ in^2
confinement effectiveness coeff.	$k_e = 0.55$ in
effective lateral stress in x direction	$f'_{l,x} = 0.041$ ksi
effective lateral stress in y direction	$f'_{l,y} = 0.037$ ksi
ratio of confined strength to unconf. strength	$f'_{cc}/f'_{co} = 1.25$
confined concrete compressive strength	$f'_{cc} = 3.6$ ksi
FRP confined concrete (Lam and Teng):	
hoop width	$b_{hoop} = 1$"
hoop spacing	$s_{frp} = 4$"
corner radius	$R_c = 1$"
ultimate hoop strain	$\varepsilon_{frp} = 0.0121$
hoop rupture strain	$\varepsilon_{h,rup} = 0.0071$

diameter of equivalent circular column $D = 19.5"$
lateral stress at rupture $f_l = 0.076$ ksi
cross sectional confined area $A_c = 346$ in^2
effectively confined area $A_e = 154$ in^2
shape factor $k_{s2} = 0.45$
concrete strain at hoop rupture (See shotcrete.)

Relations for Shotcrete

Unconfined shotcrete:
strain at spalling $\varepsilon_{sp} = 0.0053$
descending stress-strain slope $Z = 240$ ksi
FRP confined shotcrete: (same as concrete above except as noted)
concrete strain at hoop rupture $\varepsilon_{cu} = 0.0039$

Foundation Control Specimen Analysis

The effectively confined core of the FC specimen, shown in Figure B. 2, was identical to that of the FR specimen after rupture.

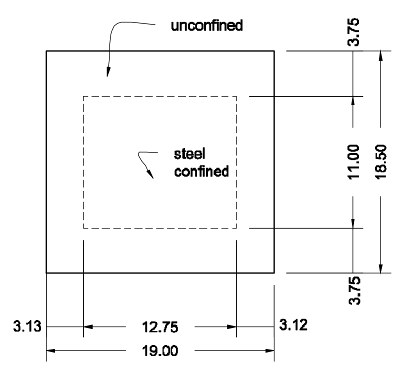


Figure B. 2 FC section dimensions and concrete regions

Steel locations and areas: (similar to AR specimen except as noted here)
@ 4" from beam bottom: $A_s = 1.0$ in^2
@ 14.5" from beam bottom: $A_s = 1.0$ in^2

Material Properties

Concrete:

cylinder compressive strength $f'_{co} = 2.88$ ksi

Young's modulus $E = 3092$ ksi

Steel:

longitudinal steel yield strength $f_y = 64.1$ ksi

transverse steel yield strength $f_y = 40$ ksi

Young's modulus $E = 29000$ ksi

Relations for Concrete

Unconfined concrete: similar to FR specimen
Steel confined concrete: similar to FR specimen

Arch Retrofitted Specimen Analysis

Geometry

The confinement regions in the AR specimen, shown in Figure B. 3, were determined similarly to the FR specimen. Near the central cap, the clear spacing between the Fibrwrap hoop was 3" leading to a 0.75" layer of effectively unconfined concrete at the perimeter. The centerline of the steel hoops was considered to be 0.75" to 1" away from the sides of the specimen. The steel hoops were staggered as shown in Chapter 4, so the spacing ranged from 4" to 8". These values were averaged and the effectively confined core was considered to be offset within the centerline of the steel hoops by a distance of 1.5"

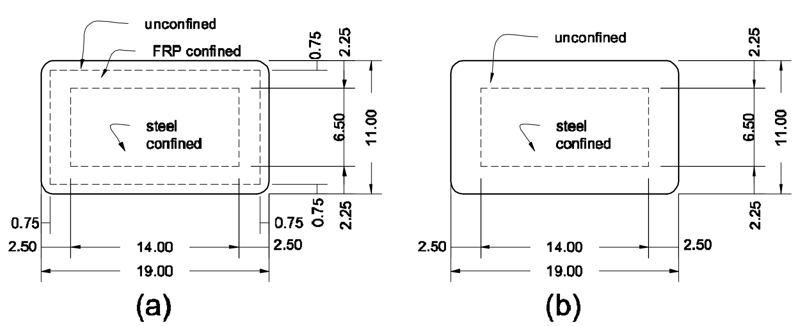


Figure B. 3 AR section dimensions and concrete regions: (a) before FRP hoop rupture; (b) after FRP hoop rupture

Steel locations and areas:

@ 1.5” from beam bottom:	$A_s = 0.88$ in^2
@ 4” from beam bottom:	$A_s = 0.44$ in^2
@ 7.” from beam bottom:	$A_s = 0.44$ in^2
@ 9.5” from beam bottom:	$A_s = 0.77$ in^2

Fibrwrap locations and areas:

@ beam top:	$A_{Fibr} = 0.36$ in^2
@ beam bottom:	$A_{Fibr} = 0.30$ in^2

Material Properties

Concrete:

cylinder compressive strength	$f'_{co} = 3.01$ ksi
Young’s modulus	$E = 3160$ ksi

Steel:

longitudinal steel yield strength	$f_y = 50.5$ ksi
transverse steel yield strength	$f_y = 40$ ksi
Young’s modulus	$E = 29000$ ksi

Fibrwrap:

tensile strength	$f_u = 81$ ksi
compressive rupture strain	$\varepsilon_{c,rup} = -0.002$
Young’s modulus	$E = 10500$ ksi

Relations for Concrete

Unconfined concrete (Kent and Park):

strain at spalling	$\varepsilon_{sp} = 0.006$
descending stress-strain slope	$Z = 201$ ksi

Steel confined concrete (Mander et al.):

hoop spacing	$s_s = 4$”
width of core	$b_{core} = 12$”
height of core	$h_{core} = 9$”
area of transverse steel in x direction	$A_{ts,x} = 0.22$ in^2

area of transverse steel in y direction	$A_{ts,y} = 0.22$ in^2
density of trans. steel in x direction	$\rho_x = 0.0061$
density of trans. steel in x direction	$\rho_y = 0.0046$
cross sectional confined core area	$A_{cc} = 105$ in^2
effectively confined core area	$A_e = 28$ in^2
confinement effectiveness coeff.	$k_e = 0.26$ in
effective lateral stress in x direction	$f'_{l,x} = 0.065$ ksi
effective lateral stress in y direction	$f'_{l,y} = 0.049$ ksi
ratio of confined strength to unconf. strength	$f'_{cc}/f'_{co} = 1.35$
confined concrete compressive strength	$f'_{cc} = 4.1$ ksi

FRP confined concrete (Lam and Teng):

hoop width	$b_{hoop} = 3$”
hoop spacing	$s_{frp} = 6$”
corner radius	$R_c = 1$”
ultimate hoop strain	$\varepsilon_{frp} = 0.0121$
hoop rupture strain	$\varepsilon_{h,rup} = 0.0071$
diameter of equivalent circular column	$D = 12.6$”
lateral stress at rupture	$f_l = 0.236$ ksi
cross sectional confined area	$A_c = 206$ in^2
effectively confined area	$A_e = 101$ in^2
shape factor	$k_{s2} = 0.64$
concrete strain at hoop rupture	$\varepsilon_{cu} = 0.0056$

Arch Control Specimen Analysis

Geometry

The effectively confined core of the AC specimen, shown in Figure B. 4Figure B. 2, was identical to that of the AR specimen after rupture.

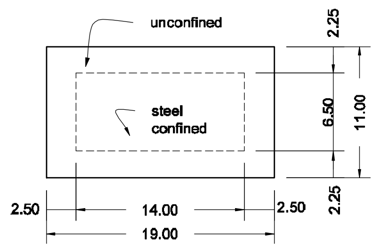


Figure B. 4 AC section dimensions and concrete regions

Steel locations and areas: (similar to AR specimen except as noted here)
@ 9.5" from beam bottom: $A_s = 0.88$ in^2

Material Properties

Concrete:
- cylinder compressive strength $f'_{co} = 3.01$ ksi
- Young's modulus $E = 3160$ ksi

Steel:
- longitudinal steel yield strength $f_y = 50.5$ ksi
- transverse steel yield strength $f_y = 40$ ksi
- Young's modulus $E = 29000$ ksi

Relations for Concrete

Unconfined concrete: similar to AR specimen
Steel confined concrete: similar to AR specimen

APPENDIX C. ANALYSIS OF ARCH SECTIONS

Retrofitted Arch-Foundation Analysis

Geometry

The concrete regions in the retrofitted arch-foundation section before and after FRP hoop rupture are shown in Figure C-1. The section is wrapped continuously with FRP, so there is no unconfined region prior to rupture, as seen in Figure C-1a. The centerline of the steel hoops is estimated to be 6" within the outside of the concrete on all sides. They are spaced at 18" on center. Thus, the boundary of the effectively confined steel core is placed a distance of 18"/4 = 4.5" within the centerline of the steel hoops. The clear spacing between the steel hoops is considered to be equal to their center-to-center spacing. Figure C-1b shows the regions after the FRP hoops have ruptured.

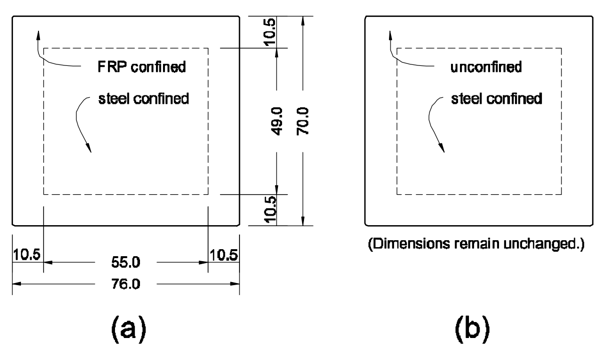


Figure C-1 Concrete regions at base of retrofitted arch: (a) before FRP hoop rupture; (b) after FRP hoop rupture

Steel locations and areas (from original construction documents and reduced by 10%):

@ 12" from bottom of section:	A_s = 14.81 in^2
@ 21" from bottom of section:	A_s = 2.28 in^2
@ 49" from bottom of section:	A_s = 2.28 in^2
@ 58" from bottom of section:	A_s = 14.81 in^2

The Fibrwrap is not considered in the section because it is terminated 1” away from the foundation.

Leadline locations and areas:

@ 2” from bottom of section:	$A_{LL} = 2.87$ in^2
@ 8” from bottom of section:	$A_{LL} = 0.22$ in^2
@ 14” from bottom of section:	$A_{LL} = 0.22$ in^2
@ 20” from bottom of section:	$A_{LL} = 0.22$ in^2
@ 26” from bottom of section:	$A_{LL} = 0.22$ in^2
@ 32” from bottom of section:	$A_{LL} = 0.22$ in^2
@ 38” from bottom of section:	$A_{LL} = 0.22$ in^2
@ 44” from bottom of section:	$A_{LL} = 0.22$ in^2
@ 50” from bottom of section:	$A_{LL} = 0.22$ in^2
@ 56” from bottom of section:	$A_{LL} = 0.22$ in^2
@ 62” from bottom of section:	$A_{LL} = 0.22$ in^2
@ 68” from bottom of section:	$A_{LL} = 2.87$ in^2

Shotcrete areas:

shotcrete depth @ bottom of section:	$d_{shot} = 6$ in
shotcrete depth @ top of section:	$d_{shot} = 6$ in

Material Properties

Concrete:

cylinder compressive strength	$f'_{co} = 2.5$ ksi
Young’s modulus	$E = 2881$ ksi

Shotcrete:

cylinder compressive strength	$f'_{co} = 4.0$ ksi
Young’s modulus	$E = 3644$ ksi

Steel:

longitudinal steel yield strength	$f_y = 33$ ksi
transverse steel yield strength	$f_y = 33$ ksi
Young’s modulus	$E = 29000$ ksi

Leadline:

tensile strength	$f_u = 205$ ksi
compressive rupture strain	$\varepsilon_{c,rup} = -0.002$
Young’s modulus	$E = 21320$ ksi

Relations for Concrete

Unconfined concrete (Kent and Park):

strain at spalling	$\varepsilon_{sp} = 0.0073$
descending stress-strain slope	$Z = 150$ ksi

Steel confined concrete (Mander el al.):

hoop spacing	$s_s = 18$"
width of core	$b_{core} = 64$"
height of core	$h_{core} = 58$"
area of transverse steel in x direction	$A_{ts,x} = 0.62$ in^2
area of transverse steel in y direction	$A_{ts,y} = 1.24$ in^2
density of trans. steel in x direction	$\rho_x = 0.0006$
density of trans. steel in x direction	$\rho_y = 0.0011$
cross sectional confined core area	$A_{cc} = 3678$ in^2
effectively confined core area	$A_e = 1963$ in^2
confinement effectiveness coeff.	$k_e = 0.53$ in
effective lateral stress in x direction	$f'_{l,x} = 0.01$ ksi
effective lateral stress in y direction	$f'_{l,y} = 0.02$ ksi
ratio of confined strength to unconf. strength	$f'_{cc}/f'_{co} = 1.1$
confined concrete compressive strength	$f'_{cc} = 2.75$ ksi

FRP confined concrete (Lam and Teng):

transverse FRP thickness	$b_{hoop} = 0.04$"
corner radius	$R_c = 1$"
ultimate hoop strain	$\varepsilon_{frp} = 0.0121$
hoop rupture strain	$\varepsilon_{h,rup} = 0.0071$
diameter of equivalent circular column	$D = 71.1$"
lateral stress at rupture	$f_l = 0.084$ ksi
cross sectional confined area	$A_c = 5277$ in^2
effectively confined area	$A_e = 1880$ in^2
shape factor	$k_{s2} = 0.37$
concrete strain at hoop rupture	(See shotcrete.)

Relations for Shotcrete

FRP confined shotcrete: (same as FRP confined concrete above except as noted)

shotcrete strain at hoop rupture	$\varepsilon_{cu} = 0.0038$

Original Arch-Foundation Analysis

Geometry

The concrete regions in the original arch section are identical to the retrofitted section without FRP confinement. This is shown in Figure C-2.

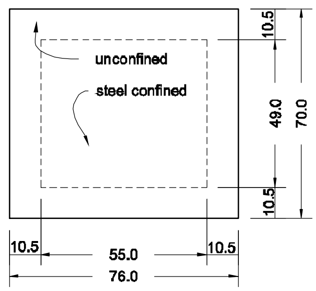


Figure C-2 Concrete regions at base of original arch

Steel locations and areas are the same as retrofitted section.

Material Properties
Concrete: similar to retrofitted section
Steel: similar to retrofitted section

Relations for Concrete
Unconfined concrete: similar to retrofitted section
Steel confined concrete: similar to retrofitted section

Retrofitted Arch Rib Analysis

Geometry

A cross section of the section of the arch rib at the third column is shown in Figure C-3. The arch rib has alternate layers of full and C-shaped wraps with the C-shaped wraps open on the intrados (at bottom of section). The C-shaped wraps appeared to provide adequate confinement for the top of the AR specimen during the test. Therefore, the C-shaped wraps are considered to behave similarly to the full wraps while the section is subjected to positive bending. This is shown in Figure C-3a. However, the region of unconfined concrete shown in this figure need not included in the model. Except for very high axial loads, the bottom of the section is in tension and the concrete stress is assumed to be zero.

The centerline of the steel hoops is estimated to be 6” within the outside of the concrete on all sides, similar to the base of the arches. They are spaced at 18” on center. Thus, the boundary of the effectively confined steel core is placed at 4.5” within the centerline of the steel hoops. Figure C-3b shows the regions after the FRP hoops have ruptured.

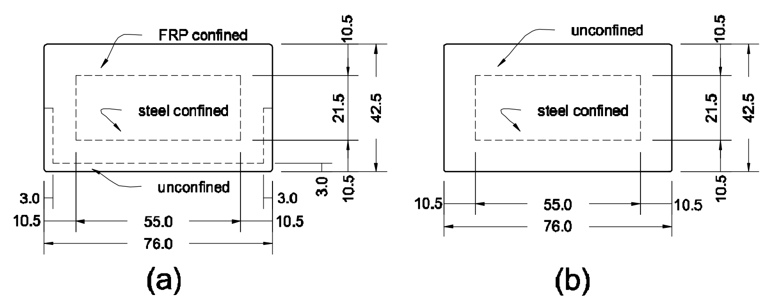


Figure C-3 Concrete regions in retrofitted arch rib at the third column: (a) before FRP hoop rupture; (b) after FRP hoop rupture

Steel locations and areas (from original construction documents and reduced 10%):

@ 6” from bottom of section:	A_s = 14.81 in^2
@ 12.75” from bottom of section:	A_s = 2.28 in^2
@ 29.75” from bottom of section:	A_s = 2.28 in^2
@ 36.5” from bottom of section:	A_s = 14.81 in^2

Fibrwrap locations and areas:

@ beam bottom:	A_{Fibr} = 4.32 in^2
@ 3” from bottom of section:	A_{Fibr} = 0.38 in^2
@ 39.3” from bottom of section:	A_{Fibr} = 0.38 in^2
@ beam top:	A_{Fibr} = 4.32 in^2

Material Properties

Concrete and steel: similar to section at arch base

Fibrwrap:

compressive rupture strain $\varepsilon_{c,rup}$ = -0.002

Young's modulus E = 10500 ksi

Relations for Concrete

Unconfined concrete (Kent and Park): similar to section at arch base

Steel confined concrete (Mander el al.): similar to section at arch base except as noted here:

height of core h_{core} = 30.5"

area of transverse steel in x direction $A_{ts,x}$ = 0.62 in^2

area of transverse steel in y direction $A_{ts,y}$ = 1.24 in^2

density of trans. steel in x direction ρ_x = 0.0006

density of trans. steel in x direction ρ_y = 0.0011

cross sectional confined core area A_{cc} = 3678 in^2

effectively confined core area A_e = 1963 in^2

confinement effectiveness coeff. k_e = 0.53 in

effective lateral stress in x direction $f'_{l,x}$ = 0.01 ksi

effective lateral stress in y direction $f'_{l,y}$ = 0.02 ksi

ratio of confined strength to unconf. strength f'_{cc}/f'_{co} = 1.1

confined concrete compressive strength f'_{cc} = 2.75 ksi

FRP confined concrete (Lam and Teng): similar to section at arch base except as noted here:

diameter of equivalent circular column D = 44.25"

lateral stress at rupture f_l = 0.067 ksi

cross sectional confined area A_c = 3195 in^2

effectively confined area A_e = 1162 in^2

shape factor k_{s2} = 0.36

concrete strain at hoop rupture ε_{cu} = 0.0041

Arch Control Specimen Analysis

Geometry

The concrete regions of the original arch sections are identical to the retrofitted sections after the FRP has ruptured. This is shown in Figure C-4.

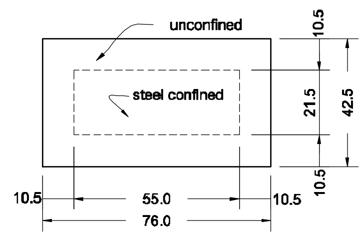


Figure C- 4 Concrete regions in original arch at the third column

Steel locations and areas are the same as retrofitted section .

Material Properties
Concrete: similar to previous sections
Steel: similar to previous sections

Relations for Concrete
Unconfined concrete: similar to previous sections
Steel confined concrete: similar to retrofitted section

APPENDIX D. STRAIN DATA

This appendix presents the strain data for the four tests. The raw data from the strain gages was first converted into strains. The data was then carefully filtered to remove the data from gages after they had broken. The strains presented here are plotted against the midspan deflection of each specimen.

The strain data for the AC (Arch Control) test is shown in Figure D-1.

The strain data for the AR (Arch Retrofitted) test is shown in Figure D-2.

The strain data for the FC (Foundation Control) test is shown in Figure D-3.

The strain data for the FR (Foundation Retrofitted) test is shown in Figure D-4.

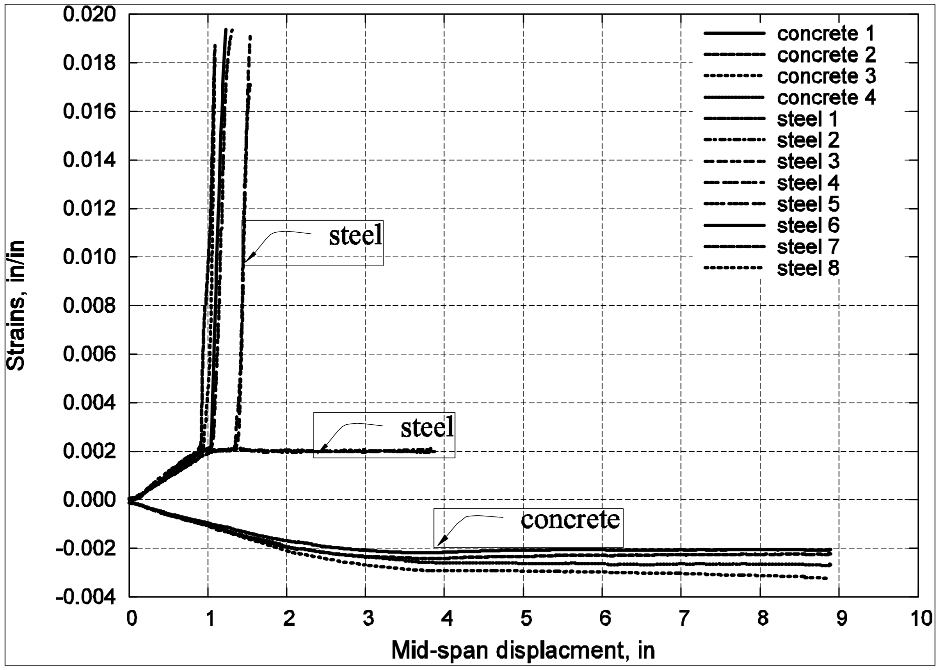


Figure D-1 Strain data for AC specimen test

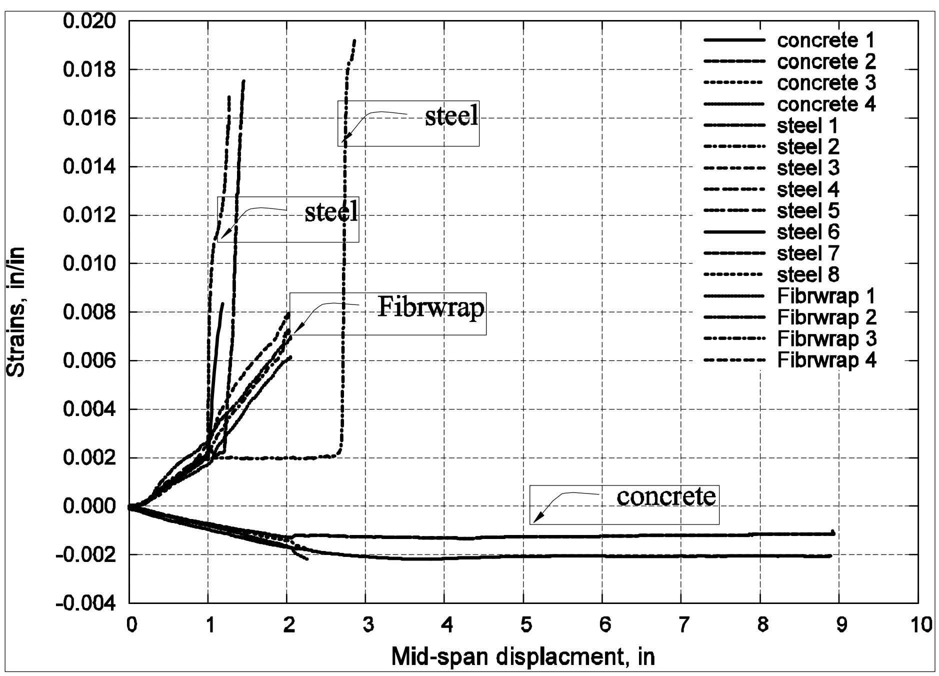


Figure D-2 Strain data for AR specimen test

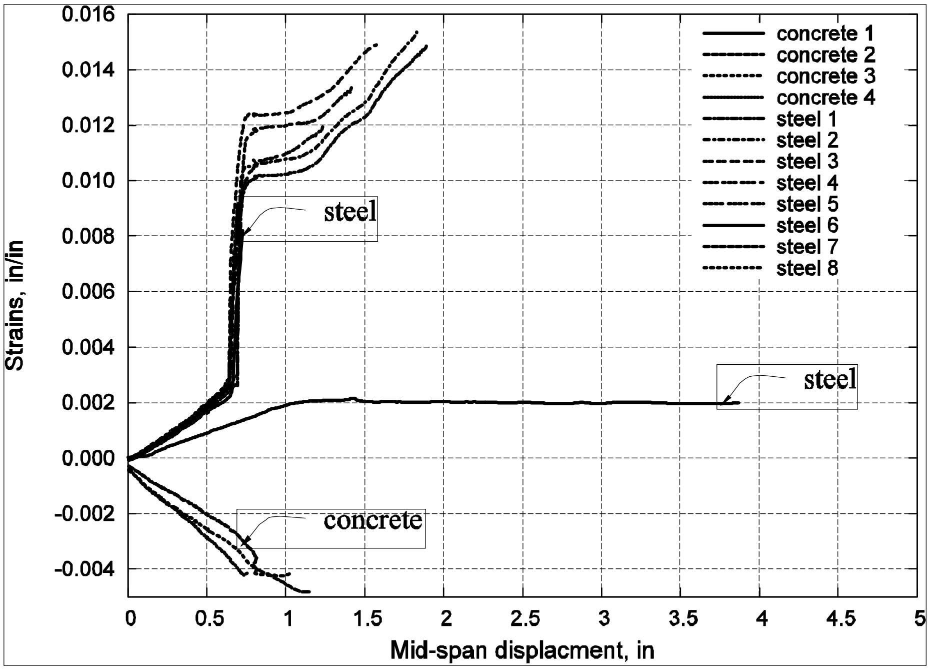


Figure D-3 Strain data for FC specimen test

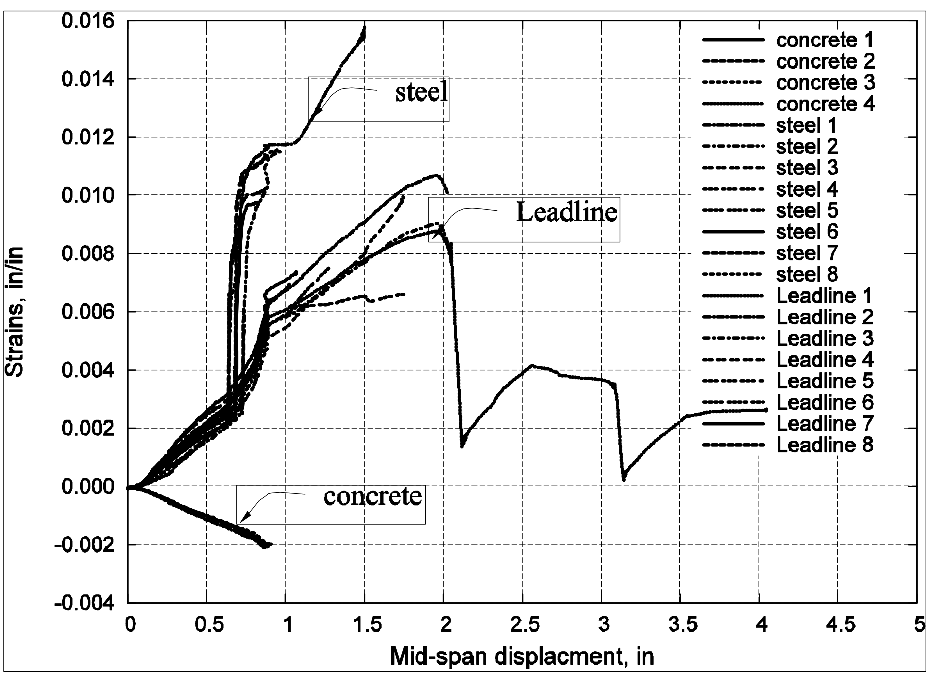


Figure D-4 Strain data for FR specimen test

APPENDIX E. PROPERTIES OF SICA FERROGARD 903

Sica FerroGard 903 is a corrosion inhibiting impregnation coating for hardened concrete surfaces. It is designed to penetrated the surface and then to diffuse in vapor or liquid form to the steel reinforcing bars embedded in the concrete. Sica FerroGard 903 forms a protective layer on the steel surface which inhibits corrosion caused by the presence of chlorides as well as by carbonation of concrete.

Color	Pale Yellow
Viscosity	15 cps
Flash Point	None (water based)
Density	1.13 (9.4 lbs./gal)
pH	11 (±1)
Application Rate	100-150 ft2/gal. total application rate

Table E-1 Properties of Sica FerroGard 903

APPENDIX F. EQUIPMENT LIST FOR STRUCTURE HEALTH MONITORING OF CASTLEWOOD CANYON BRIDGE

Below is the equipments capable of measuring parameters important to both long-term corrosion monitoring including linear polarization resistance(LPR), open circuit potential (OCP), resistivity, chloride ion concentration([Cl-]) and temperature, and strain on the arch in the Castlewood Canyon Bridge located in Franktown, Colorado. Twenty strain gages were purchased from Measurement Group. One of the 20 strain gages will be tested in the laboratory. Therefore, strains in the nineteen locations can be monitored on the arch repaired with CFRP. Three ECI-1 corrosion instruments were purchased from Virginia Technologies. However, one of three ECI-1 corrosion instruments cannot be measured because the cable was cut by the workers during the construction. Therefore, corrosion monitoring of steel reinforced concrete in the Arch can be monitored by two embedded corrosion instruments.

Table F-1 Equipment List

Item	Description	QTY
Loggernet	Datalogger Support Software	1
CR10X	Measurement & Control Module with 128K Memory, Wiring Panel, Screwdriver	1
XT-CR10X	CR10X Tested to Extended Temperature	1
BP24	12V Sealed Rechargeable Battery, 24AHR	1
MSX20	20W Solar Panel, 10ft Cable	1
CH12R	12V Charger/Regulator	1
9591	Transformer (wall plug) AC/AC 110VAC to 18VAC 1.1A, 6ft Cable	1
15873	ENC 16/18 Weather-Resistant Enclosure 16 x 18inch	1
10628	ENC 16/18 Option with 2 conduits for cables	1
7841	Enclosure Mounts Triple notch for use with UT20 & UT 30	1
15663	SC32B Optically Isolated RS232 Interface	1
4WFB350	4WFB 350 Ohm 4-wire Full Bridge Tim Module	20
AM16/32	AM16/32 16 or 32 Channel Relay Multiplexer	2
XT-AM 16/32	AM 16/32 Tested to Extended Temp	2
15664	SC932A CS I/O to 9-Pin RS232 DCE Interface	1
17260	Redwing CDMA Airlink Cellular Digital Modem	1
14394	Redwing Mounting Kit with Cable	1
14454	Antenna Cellular 800MHZ YAGI 8DBD with Type N Female, 10ft Cable	1
ECI-1	Embedded Corrosion Instrument (Virginia Technologies, Inc.)	3
EA-06-250AE-350	General Purpose strain gage with high-dissipation grid. (Measurements Group, Inc)	20

APPENDIX G. DATALOGGING PROGRAM

The program is divided by measuring microstrains and corrosion related 5 parameters. For measurement of microstrains, it scans every 10 seconds, and saves every 5 minutes. For ECI-1 sensors, it scans every 30 minute and saves every 30 minutes. Communication with Redwing Cell Modem can be performed between 8 am and 4 pm. So, during the period, collected data at datalogger can be received between 8 am and 4 pm everyday.

```
*Table 1 Program
  01: 10       Execution Interval (seconds)

;==============================
; COMMUNICATION ENABLE/DISABLE
;==============================
; This instructions describes to communicate with Redwing Cell Modem.
; Turn on 8 AM and Turn off 4 PM in every day.

1:  If time is (P92)
 1: 480      Minutes (Seconds --) into a
 2: 1440     Interval (same units as above)
 3: 47       Set Port 7 High
2:  If time is (P92)
 1: 960      Minutes (Seconds --) into a
 2: 1440     Interval (same units as above)
 3: 57       Set Port 7 Low
3:  If time is (P92)
 1: 480      Minutes (Seconds --) into a
 2: 1440     Interval (same units as above)
 3: 14       Set Flag 4 High
4:  If time is (P92)
 1: 1020     Minutes (Seconds --) into a
 2: 1440     Interval (same units as above)
 3: 24       Set Flag 4 Low
5:  If Flag/Port (P91)
 1: 14       Do if Flag 4 is High
 2: 30       Then Do
6:  Do (P86)
 1: 44       Set Port 4 High ; Reset and Enable the AM16/32.
7:  Beginning of Loop (P87)
 1: 0        Delay
 2: 16       Loop Count
    8:  Do (P86)
     1: 73       Pulse Port 3 ; Clock forward to the next bank on the AM16/32.

    9:  Excitation with Delay (P22) ; Delay to allow relay connection to settle.
     1: 2        Ex Channel
```

```
     2: 0        Delay W/Ex (units = 0.01 sec)
     3: 5        Delay After Ex (units = 0.01 sec)
     4: 0        mV Excitation
    10:  Full Bridge (P6)
     1: 1        Reps
     2: 2        7.5 mV Slow Range
     3: 1        DIFF Channel
     4: 1        Excite all reps w/Exchan 1
     5: 2500     mV Excitation
     6: 1     -- Loc [ mVPerVG01 ]
     7: 1.0      Mult
     8: 0.0      Offset
11:  End (P95)

12:  Do (P86)
 1: 54       Set Port 4 Low
13:  Do (P86)
 1: 42       Set Port 2 High ; Reset and Enable the Second AM16/32.
14:  Beginning of Loop (P87)
 1: 0        Delay
 2: 4        Loop Count
    15:  Do (P86)
     1: 73       Pulse Port 3 ; Clock forward to the next bank on the AM16/32.
    16:  Excitation with Delay (P22) ; Delay to allow relay connection to settle.
     1: 2        Ex Channel
     2: 0        Delay W/Ex (units = 0.01 sec)
     3: 5        Delay After Ex (units = 0.01 sec)
     4: 0        mV Excitation
    17:  Full Bridge (P6)
     1: 1        Reps
     2: 2        7.5 mV Slow Range
     3: 2        DIFF Channel
     4: 2        Excite all reps w/Exchan 2
     5: 2500     mV Excitation
     6: 17    -- Loc [ mVperVG17 ]
     7: 1.0      Mult
     8: 0.0      Offset
18:  End (P95)

19:  Do (P86)
 1: 52       Set Port 2 Low ; Deactivate the AM16/32.
20:  If Flag/Port (P91) ; If first time through then call zero routine.
 1: 21       Do if Flag 1 is Low
 2: 1        Call Subroutine 1
21:  Beginning of Loop (P87)
 1: 0        Delay
 2: 20       Loop Count
    22:  Step Loop Index (P90)
     1: 1        Step
    23:  Z=X-Y (P35) ; Subtract zeroed value from measurement.
     1: 1     -- X Loc [ mVPerVG01 ]
     2: 21    -- Y Loc [ mVPerVZ01 ]
```

```
    3: 41       Z Loc [ Vr_1      ]
   24:  Z=X*F (P37)
    1: 41       X Loc [ Vr_1      ]
    2: .001     F
    3: 41       Z Loc [ Vr_1      ]
   25:  Z=X*F (P37)
    1: 41       X Loc [ Vr_1      ]
    2: -2       F
    3: 42       Z Loc [ One_2Vr   ]
   26:  Z=Z+1 (P32)
    1: 42       Z Loc [ One_2Vr   ]
   27:  Z=X/Y (P38)
    1: 41       X Loc [ Vr_1      ]
    2: 42       Y Loc [ One_2Vr   ]
    3: 43       Z Loc [ Vr_1_2Vr  ]

   28:  Z=X/Y (P38)
    1: 43       X Loc [ Vr_1_2Vr  ]
    2: 44    -- Y Loc [ AdjGF01   ]
    3: 64    -- Z Loc [ uStrain01 ]

   29:  Z=X*Y (P36)
    1: 64    -- X Loc [ uStrain01 ]
    2: 84       Y Loc [ Number4e6 ]
    3: 64    -- Z Loc [ uStrain01 ]
30:  End (P95)

31:  If Flag/Port (P91)
 1: 23       Do if Flag 3 is Low
 2: 30       Then Do
   32:  If time is (P92)
    1: 0        Minutes (Seconds --) into a
    2: 10       Interval (same units as above)
    3: 2        Call Subroutine 2 ; Outputs data to FinalStorage.
33:  End (P95)
34:  End (P95)

*Table 2 Program
  02: 1800      Execution Interval (seconds)

1:  Batt Voltage (P10)
 1: 187      Loc [ Logger_V  ]
2:  Internal Temperature (P17)
 1: 188      Loc [ logger_T  ]
3:  If Flag/Port (P91)
 1: 26       Do if Flag 6 is Low
 2: 30       Then Do
4:  SDI-12 Recorder (P105)
 1: 1        SDI-12 Address
 2: 10       Start Verification (aV!)
 3: 5        Port
 4: 172      Loc [ CHLORIDE  ]
```

```
 5: 1.0      Mult
 6: 0.0      Offset
5:  SDI-12 Recorder (P105)
 1: 1        SDI-12 Address
 2: 11       Send Identification (aI!)
 3: 5        Port
 4: 189      Loc [ I_dummy   ]
 5: 1.0      Mult
 6: 0.0      Offset
6:  Do (P86)
 1: 3        Call Subroutine 3
7:  SDI-12 Recorder (P105)
 1: 1        SDI-12 Address
 2: 10       Start Verification (aV!)
 3: 6        Port
 4: 172      Loc [ CHLORIDE  ]
 5: 1.0      Mult
 6: 0.0      Offset
8:  SDI-12 Recorder (P105)
 1: 1        SDI-12 Address
 2: 11       Send Identification (aI!)
 3: 6        Port
 4: 189      Loc [ I_dummy   ]
 5: 1.0      Mult
 6: 0.0      Offset
9:  Do (P86)
 1: 5        Call Subroutine 5
10:  Do (P86)
 1: 16       Set Flag 6 High
11:  End (P95)
12:  SDI-12 Recorder (P105)
 1: 1        SDI-12 Address
 2: 0        Start Measurement (aM!)
 3: 5        Port
 4: 190      Loc [ C_1       ]
 5: 1.0      Mult
 6: 0.0      Offset
13:  If (X<=>F) (P89)
 1: 190      X Loc [ C_1       ]
 2: 3        >=
 3: -99998   F
 4: 4        Call Subroutine 4
14:  SDI-12 Recorder (P105)
 1: 1        SDI-12 Address
 2: 0        Start Measurement (aM!)
 3: 6        Port
 4: 190      Loc [ C_1       ]
 5: 1.0      Mult
 6: 0.0      Offset
15:  If (X<=>F) (P89)
 1: 190      X Loc [ C_1       ]
 2: 3        >=
```

```
 3: -99998   F
 4: 6       Call Subroutine 6

*Table 3 Subroutines
1:  Beginning of Subroutine (P85)
 1: 1       Subroutine 1
    2:  Do (P86) ; Setup so Subroutine does not get called again.
     1: 11      Set Flag 1 High
    3:  Z=F (P30) ; Lead Length Resistance per 100 feet.
     1: 2.5     F ; 0.025 Ohms/Foot for 24 gauge copper stranded wire.
     2: 0       Exponent of 10
     3: 85      Z Loc [ LeadOhms  ]
    4:  Bulk Load (P65)
     1: 0.0     F ; Gage01
     2: 0.0     F ; Gage02
     3: 0.0     F ; Gage03
     4: 0.0     F ; Gage04
     5: 0.0     F ; Gage05
     6: 0.0     F ; Gage06
     7: 0.0     F ; Gage07
     8: 0.0     F ; Gage08
     9: 86      Loc [ LeadFt01  ]
    5:  Bulk Load (P65)
     1: 0.0     F ; Gage09
     2: 0.0     F ; Gage10
     3: 0.0     F ; Gage11
     4: 0.0     F ; Gage12
     5: 0.0     F ; Gage13
     6: 0.0     F ; Gage14
     7: 0.0     F ; Gage15
     8: 0.0     F ; Gage16
     9: 94      Loc [ LeadFt09  ]
    6:  Bulk Load (P65)
     1: 0.0     F ; Gage17
     2: 0.0     F ; Gage18
     3: 0.0     F ; Gage19
     4: 0.0     F ; Gage20
     5: 0.0     F ; Gage00
     6: 0.0     F ; Gage00
     7: 0.0     F ; Gage00
     8: 0.0     F ; Gage00
     9: 102     Loc [ LeadFt17  ]
    7:  Beginning of Loop (P87)
     1: 0       Delay
     2: 20      Loop Count
        8:  Z=X*Y (P36)
         1: 86    -- X Loc [ LeadFt01  ]
         2: 85       Y Loc [ LeadOhms  ]
         3: 106   -- Z Loc [ OhmLead01 ]
    9:  End (P95)
    10:  Bulk Load (P65)
     1: 2.095    F ; Gauge01
```

```
 2: 2.095    F ; Gauge02
 3: 2.095    F ; Gauge03
 4: 2.095    F ; Gauge04
 5: 2.095    F ; Gauge05
 6: 2.095    F ; Gauge06
 7: 2.095    F ; Gauge07
 8: 2.095    F ; Gauge08
 9: 126      Loc [ GF01      ]
11:  Bulk Load (P65)
 1: 2.095    F ; Gauge09
 2: 2.095    F ; Gauge10
 3: 2.095    F ; Gauge11
 4: 2.095    F ; Gauge12
 5: 2.095    F ; Gauge13
 6: 2.095    F ; Gauge14
 7: 2.095    F ; Gauge15
 8: 2.095    F ; Gauge16
 9: 134      Loc [ GF09      ]
12:  Bulk Load (P65)
 1: 2.095    F ; Gauge17
 2: 2.095    F ; Gauge18
 3: 2.095    F ; Gauge19
 4: 2.095    F ; Gauge20
 5: 0        F ; Gauge0
 6: 0        F ; Gauge0
 7: 0        F ; Gauge0
 8: 0        F ; Gauge0
 9: 142      Loc [ GF17      ]
13:  Bulk Load (P65)
 1: 350      F ; Gage01
 2: 350      F ; Gage02
 3: 350      F ; Gage03
 4: 350      F ; Gage04
 5: 350      F ; Gage05
 6: 350      F ; Gage06
 7: 350      F ; Gage07
 8: 350      F ; Gage08
 9: 146      Loc [ G01Ohms   ]
14:  Bulk Load (P65)
 1: 350      F ; Gage09
 2: 350      F ; Gage10
 3: 350      F ; Gage11
 4: 350      F ; Gage12
 5: 350      F ; Gage13
 6: 350      F ; Gage14
 7: 350      F ; Gage15
 8: 350      F ; Gage16
 9: 154      Loc [ G09Ohms   ]
15:  Bulk Load (P65)
 1: 350      F ;Gage17
 2: 350      F
 3: 350      F
```

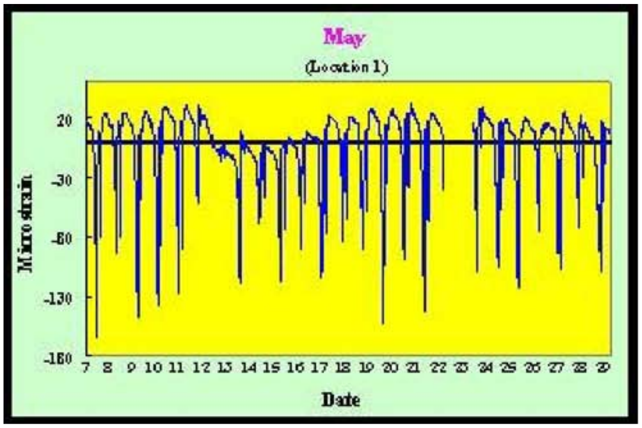
```
    4: 350      F
    5: 0.0      F
    6: 0.0      F
    7: 0.0      F
    8: 0.0      F
    9: 162      Loc [ G17Ohms   ]
   16:  Z=F (P30) ; Load in the large number, 4000.0
    1: 4        F
    2: 6        Exponent of 10
    3: 84       Z Loc [ Number4e6 ]
   17:  Beginning of Loop (P87)
    1: 0        Delay
    2: 20       Loop Count
       18:  Z=X+Y (P33) ; Calculate GOhms+LeadOhms
        1: 146   -- X Loc [ G01Ohms   ]
        2: 106   -- Y Loc [ OhmLead01 ]
        3: 166      Z Loc [ GAndLOhms ]
       19:  Z=X/Y (P38) ; Calculate RG/(RG + RL)
        1: 146   -- X Loc [ G01Ohms   ]
        2: 166      Y Loc [ GAndLOhms ]
        3: 167      Z Loc [ AdjFactor ]
       20:  Z=X*Y (P36) ; Calculate adjusted GaugeFactor, GF*[RG/(RG + RL)]
        1: 167      X Loc [ AdjFactor ]
        2: 126   -- Y Loc [ GF01      ]
        3: 44    -- Z Loc [ AdjGF01   ]
       21:  Z=X (P31) ; Load last gauge measurements.
        1: 1     -- X Loc [ mVPerVG01 ]
        2: 21    -- Z Loc [ mVPerVZ01 ]
   22:  End (P95)
   23:  Do (P86) ; Store zero measurement values and adjusted gauge factors.
    1: 10       Set Output Flag High (Flag 0)
   24:  Set Active Storage Area (P80)^13331
    1: 1        Final Storage Area 1
    2: 110      Array ID
   25:  Real Time (P77)^19880
    1: 1221     Year,Day,Hour/Minute,Seconds (midnight = 2400)
   26:  Sample (P70)^22627
    1: 20       Reps
    2: 21       Loc [ mVPerVZ01 ]
   27:  Sample (P70)^11346
    1: 20       Reps
    2: 44       Loc [ AdjGF01   ]
   28:  Do (P86)
    1: 20       Set Output Flag Low (Flag 0)
29:  End (P95)

30:  Beginning of Subroutine (P85) ; Output data to FinalStorage.
 1: 2       Subroutine 2

   31:  Do (P86)
    1: 10       Set Output Flag High (Flag 0)
   32:  Set Active Storage Area (P80)^30416
```

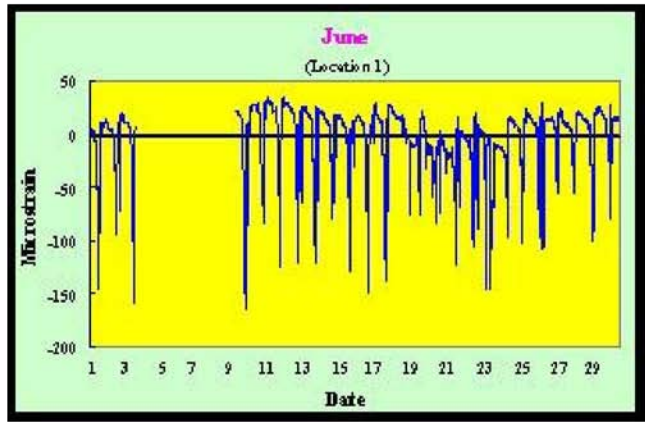
```
     1: 1        Final Storage Area 1
     2: 130      Array ID
    33:  Real Time (P77)^16027
     1: 1221     Year,Day,Hour/Minute,Seconds (midnight = 2400)
    34:  Sample (P70)^1222;Output microstrain
     1: 20       Reps
     2: 64       Loc [ uStrain01 ]
    35:  Sample (P70) ^26393;  Output raw mVolt per Volt from gauges
     1: 20       Reps
     2: 1        Loc [ mVPerVG01 ]
    36:  Do (P86)
     1: 20       Set Output Flag Low (Flag 0)
37:  End (P95)
38:  Beginning of Subroutine (P85)
 1: 3        Subroutine 3
    39:  Do (P86)
     1: 10       Set Output Flag High (Flag 0)

    40:  Set Active Storage Area (P80)^17375
     1: 1        Final Storage Area 1
     2: 200      Array ID
    41:  Real Time (P77)^24160
     1: 1110     Year,Day,Hour/Minute (midnight = 0000)
    42:  Resolution (P78)
     1: 0        Low Resolution
    43:  Sample (P70)^22
     1: 2        Reps
     2: 187      Loc [ Logger_V  ]
    44:  Resolution (P78)
     1: 1        High Resolution
    45:  Sample (P70)^12555
     1: 5        Reps
     2: 172      Loc [ CHLORIDE  ]
46:  End (P95)

47:  Beginning of Subroutine (P85)
 1: 4        Subroutine 4
    48:  Do (P86)
     1: 10       Set Output Flag High (Flag 0)
    49:  Set Active Storage Area (P80)^7419
     1: 1        Final Storage Area 1
     2: 240      Array ID
    50:  Real Time (P77)^26425
     1: 1110     Year,Day,Hour/Minute (midnight = 0000)
    51:  Resolution (P78)
     1: 0        Low Resolution
    52:  Sample (P70)^9705
     1: 2        Reps
     2: 187      Loc [ Logger_V  ]
    53:  Resolution (P78)
     1: 1        High Resolution
    54:  Sample (P70)^6871
```

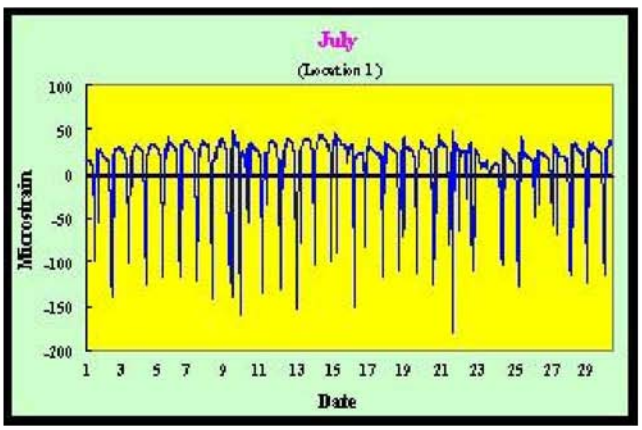
```
     1: 5        Reps
     2: 190      Loc [ C_1       ]
55:  End (P95)


56:  Beginning of Subroutine (P85)
 1: 5        Subroutine 5
    57:  Do (P86)
     1: 10       Set Output Flag High (Flag 0)
    58:  Set Active Storage Area (P80)^14797
     1: 1        Final Storage Area 1
     2: 210      Array ID
    59:  Real Time (P77)^24160
     1: 1110     Year,Day,Hour/Minute (midnight = 0000)
    60:  Resolution (P78)
     1: 0        Low Resolution
    61:  Sample (P70)^22
     1: 2        Reps
     2: 187      Loc [ Logger_V  ]

    62:  Resolution (P78)
     1: 1        High Resolution
    63:  Sample (P70)^12555
     1: 5        Reps
     2: 172      Loc [ CHLORIDE  ]
64:  End (P95)

65:  Beginning of Subroutine (P85)
 1: 6        Subroutine 6
    66:  Do (P86)
     1: 10       Set Output Flag High (Flag 0)
    67:  Set Active Storage Area (P80)^5723
     1: 1        Final Storage Area 1
     2: 250      Array ID
    68:  Real Time (P77)^26425
     1: 1110     Year,Day,Hour/Minute (midnight = 0000)
    69:  Resolution (P78)
     1: 0        Low Resolution
    70:  Sample (P70)^9705
     1: 2        Reps
     2: 187      Loc [ Logger_V  ]
    71:  Resolution (P78)
     1: 1        High Resolution
    72:  Sample (P70)^12954
     1: 5        Reps
     2: 190      Loc [ C_1       ]
73:  End (P95)
End Program
```

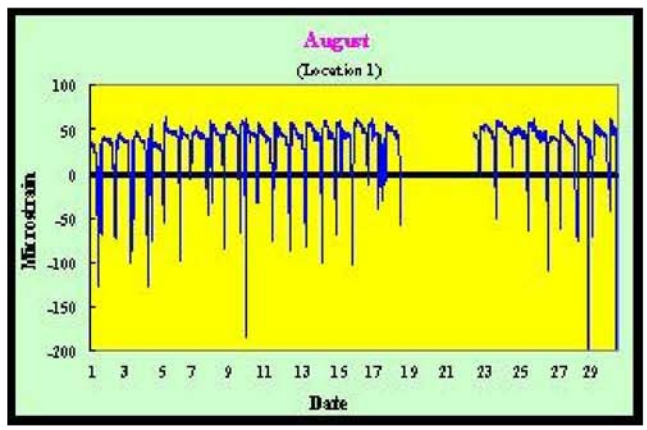
APPENDIX H. CURRENT STRAIN PROFILE (MAY, 7 ~ OCTOBER 7, 2004)

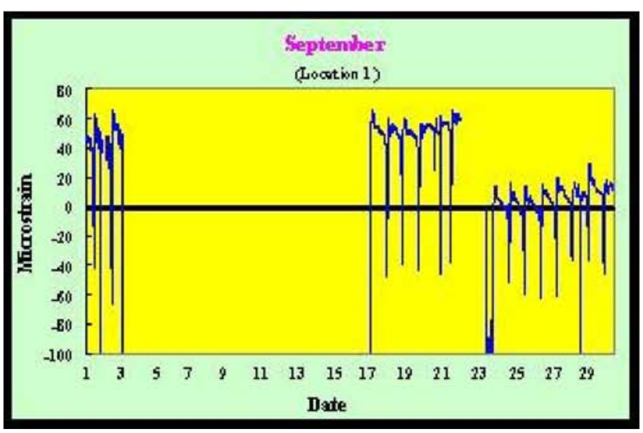
Location 1

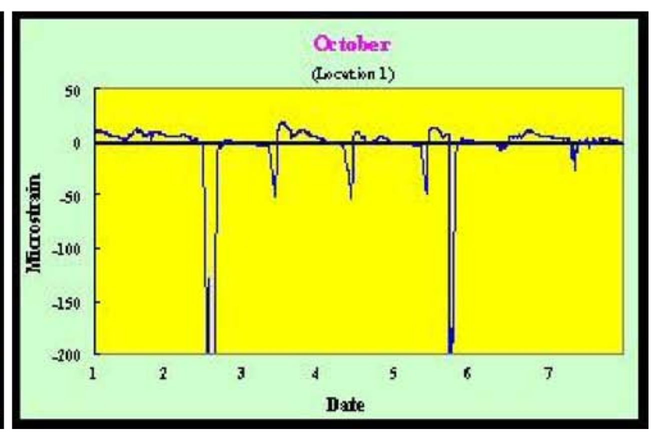




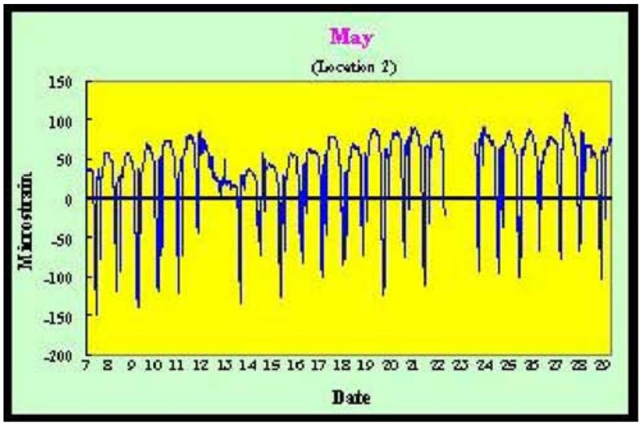


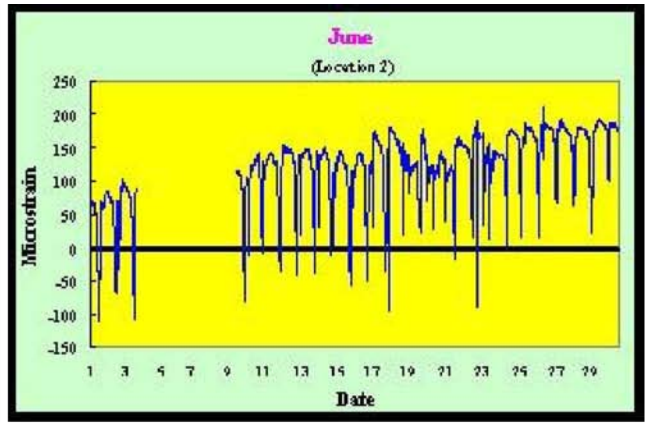


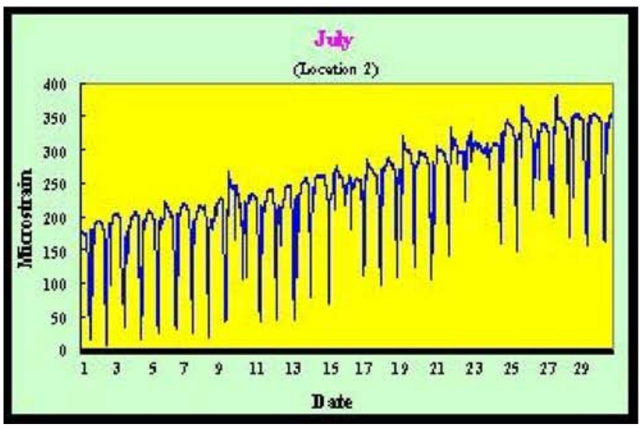


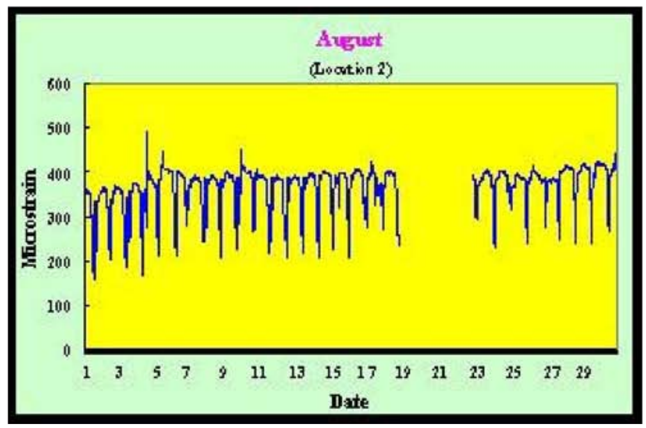


Location 2

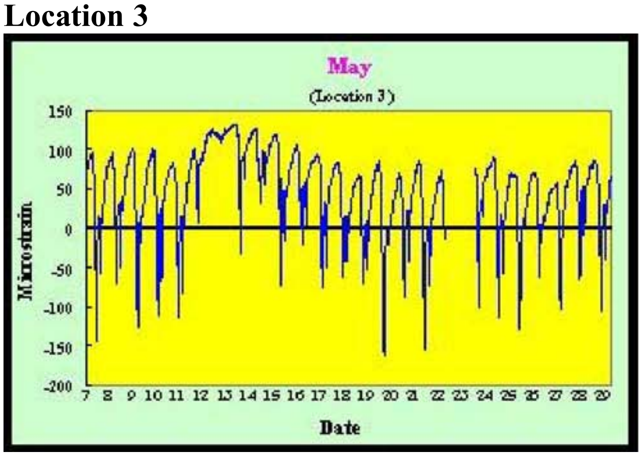


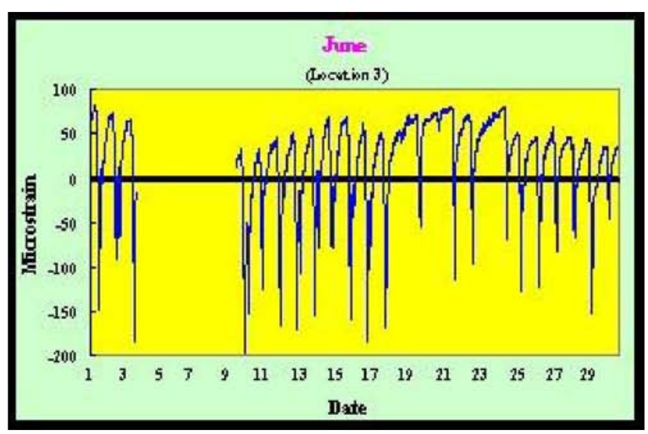


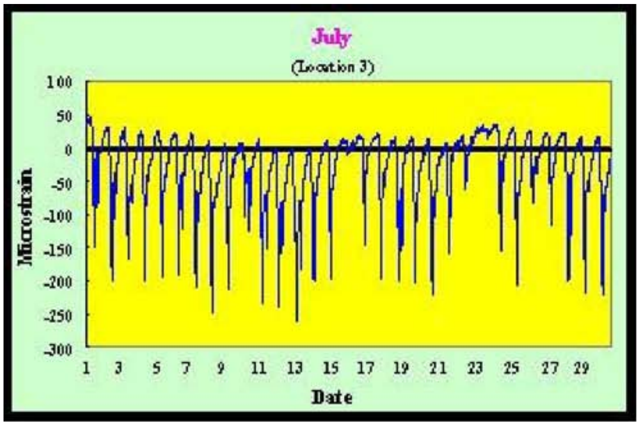


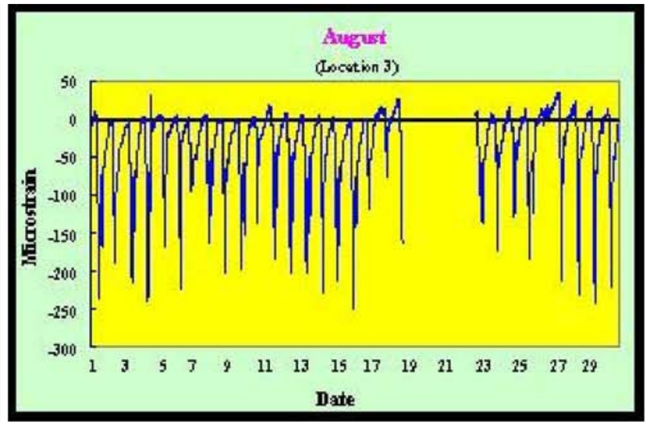


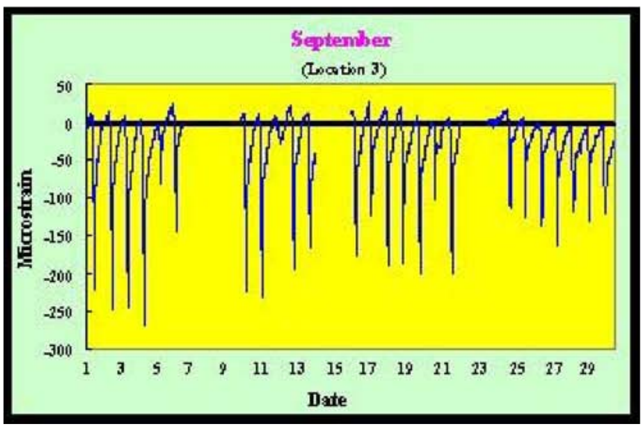
Location 3

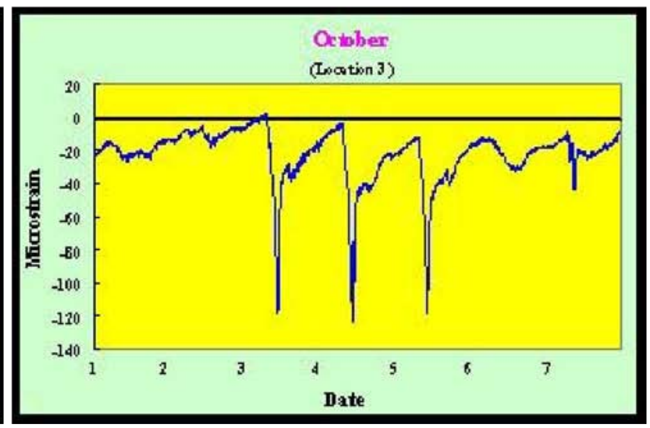




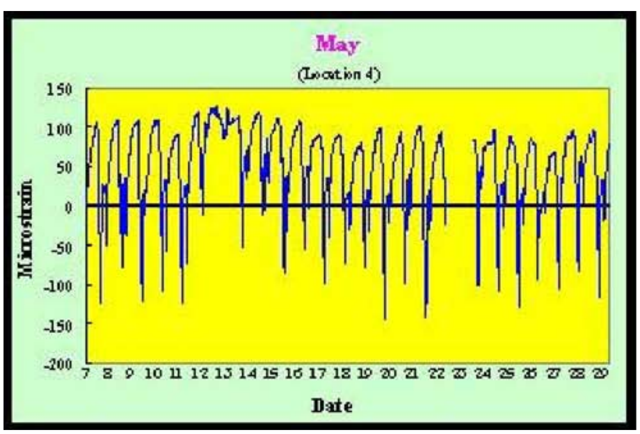

July
(Location 3)
Microstrain
Date

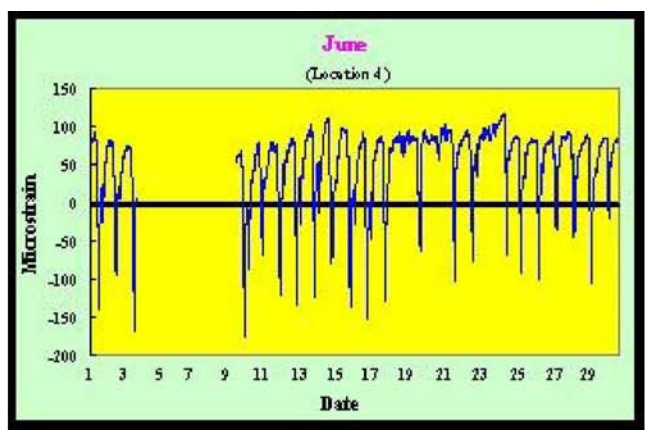

August
(Location 3)
Microstrain
Date

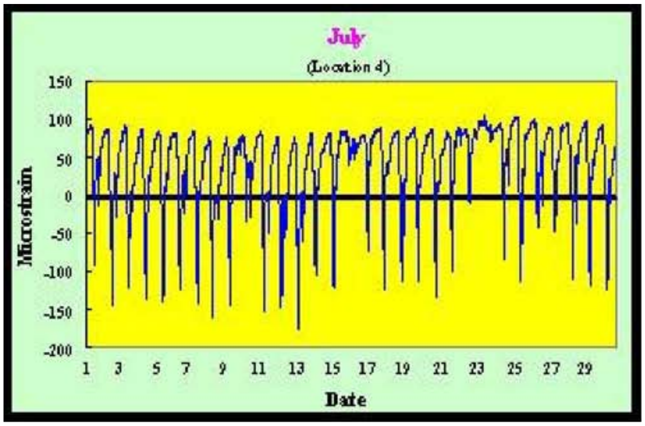

September
(Location 3)
Microstrain
Date

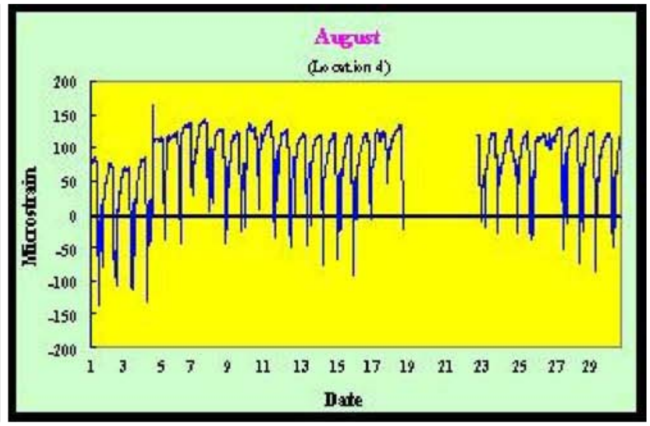

October
(Location 3)
Microstrain
Date

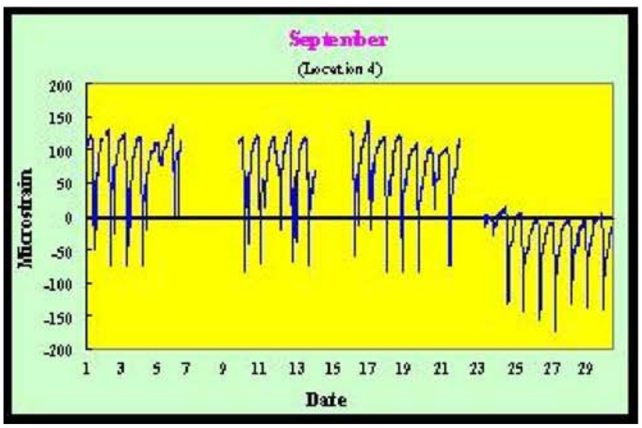
Location 4

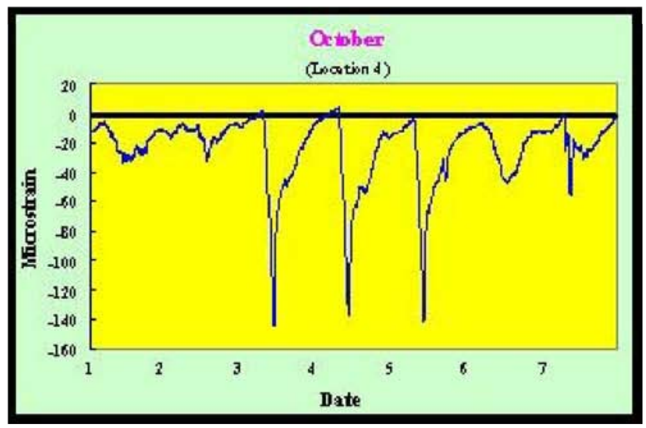

May
(Location 4)
Microstrain
Date


June
(Location 4)
Microstrain
Date

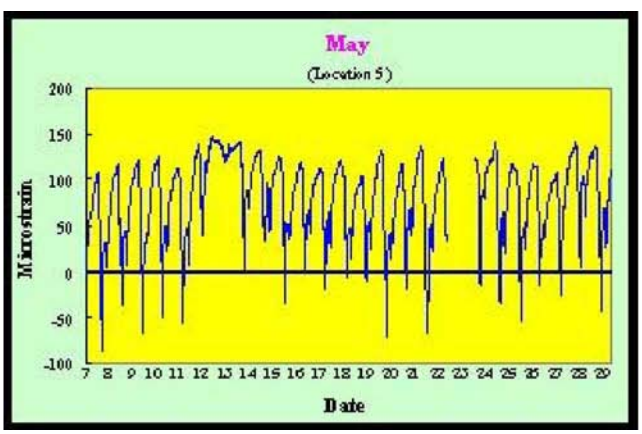

July
(Location 4)
Microstrain
Date

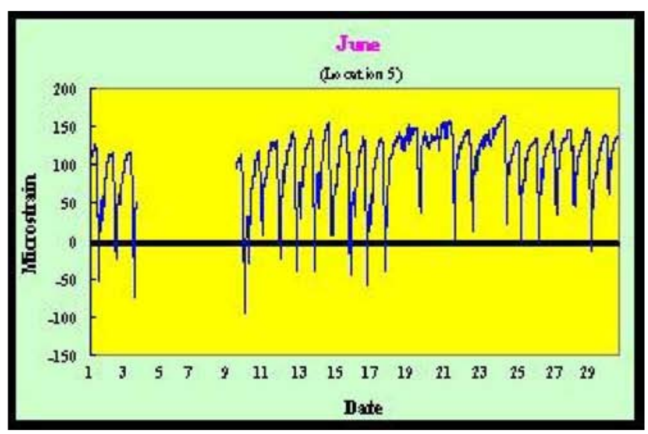

August
(Location 4)
Microstrain
Date

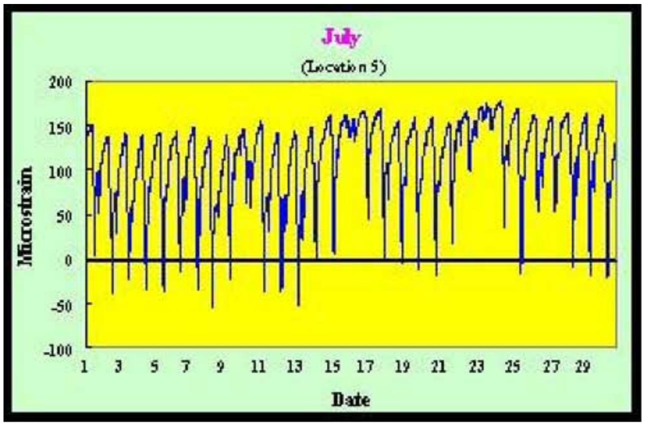

September
(Location 4)
Microstrain
Date

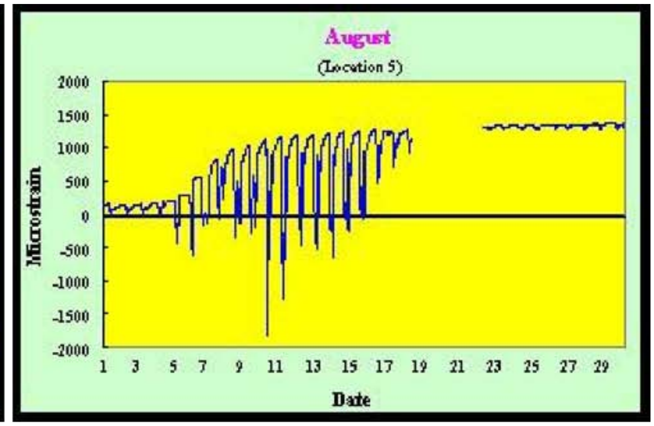

October
(Location 4)
Microstrain
Date

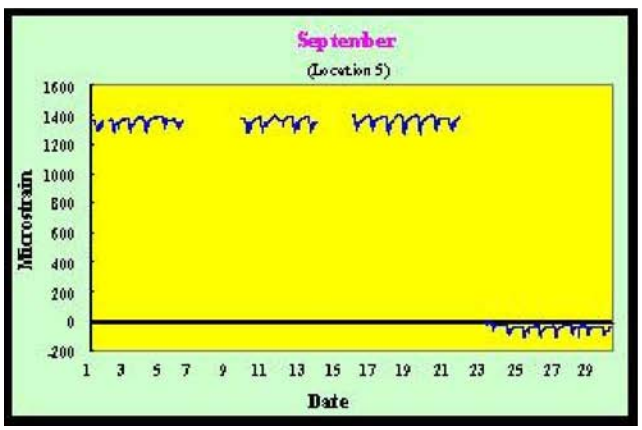
Location 5

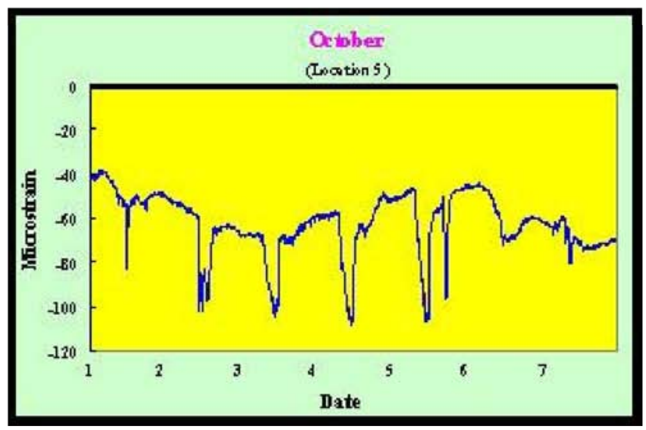

May
(Location 5)
Microstrain
Date


June
(Location 5)
Microstrain
Date

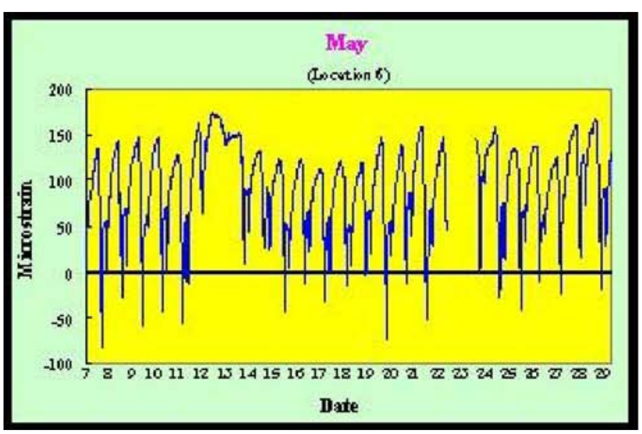

July
(Location 5)
Microstrain
Date

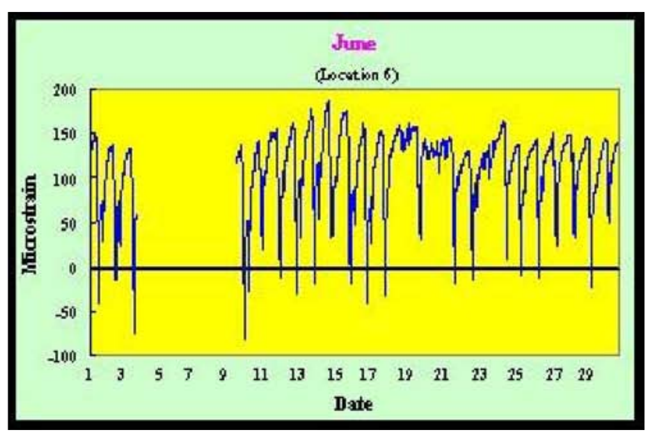

August
(Location 5)
Microstrain
Date

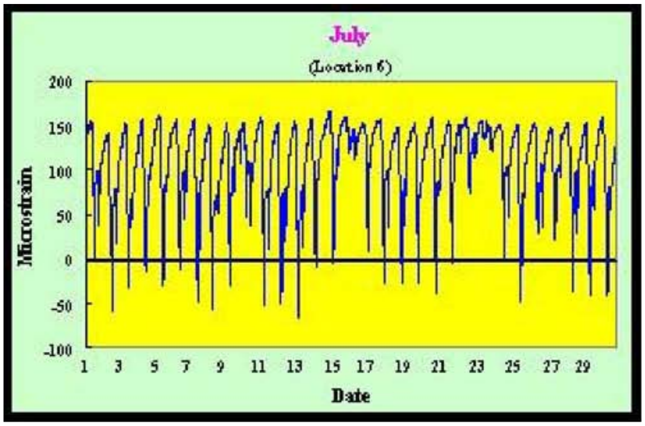

September
(Location 5)
Microstrain
Date

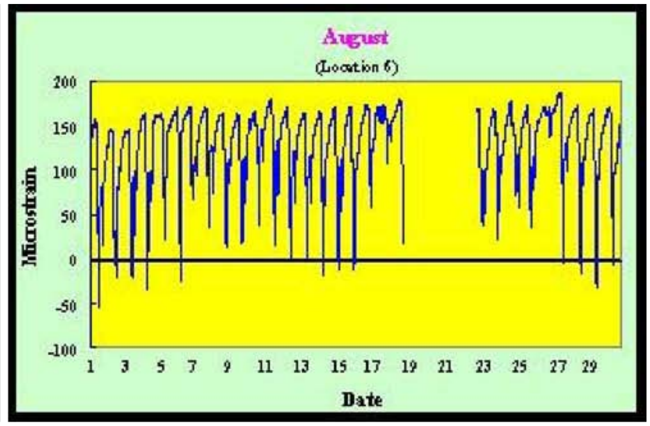

October
(Location 5)
Microstrain
Date

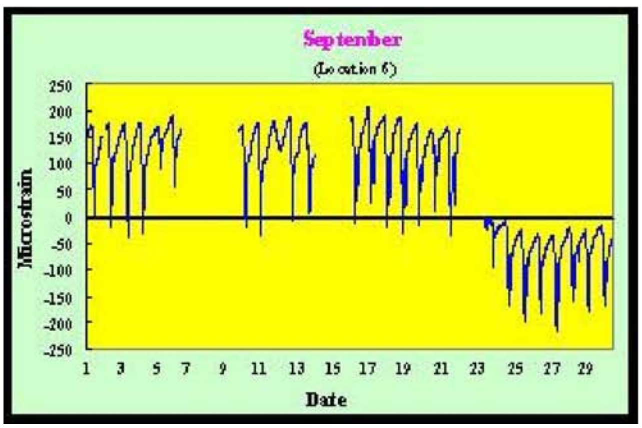
Location 6

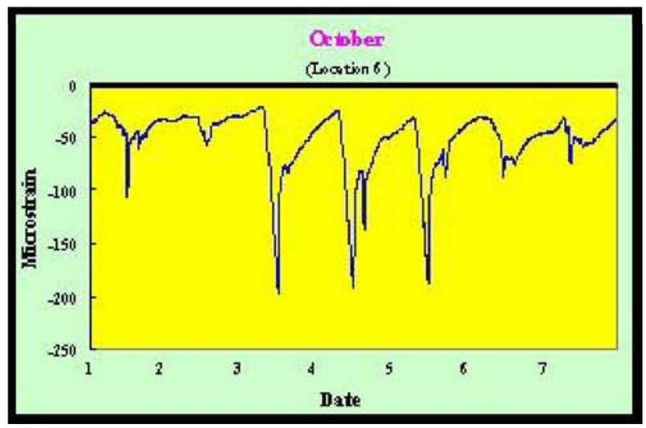

May
(Location 6)
Microstrain
Date


June
(Location 6)
Microstrain
Date

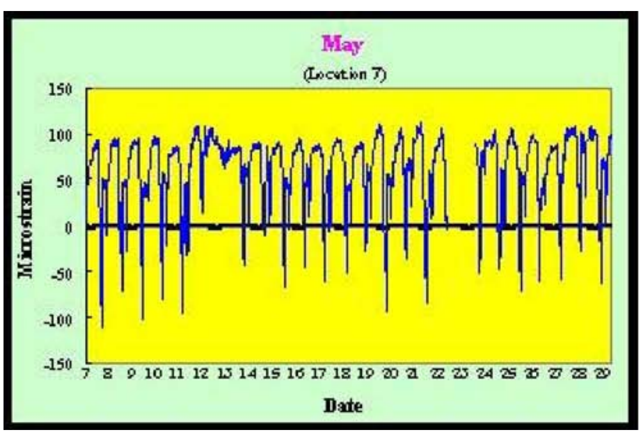

July
(Location 6)
Microstrain
Date

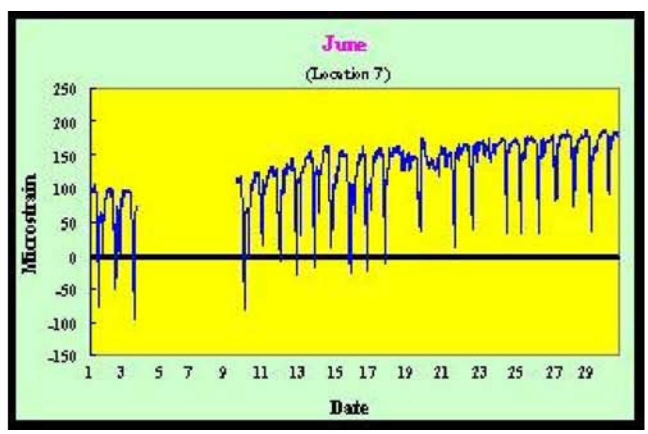

August
(Location 6)
Microstrain
Date

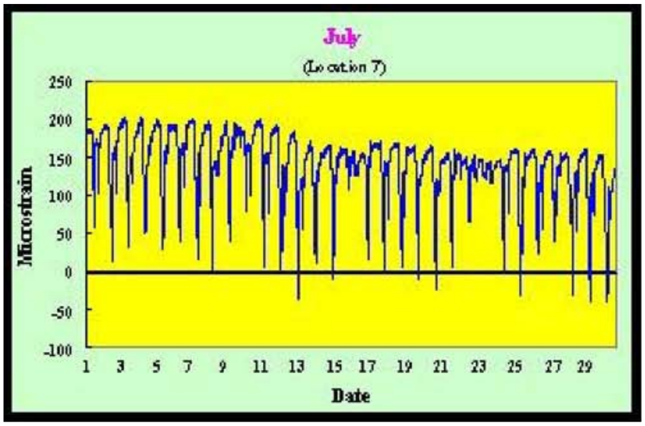

September
(Location 6)
Microstrain
Date

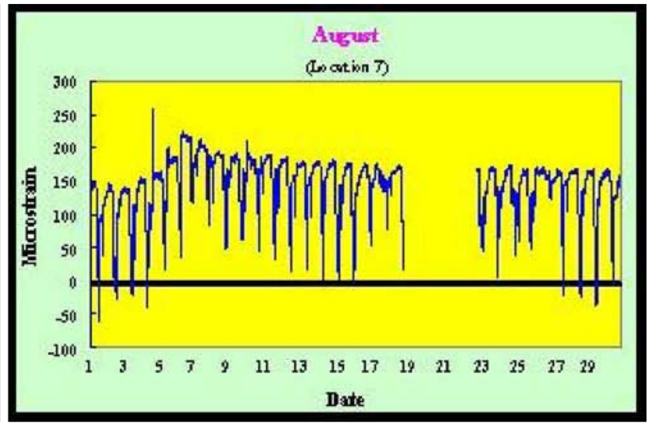

October
(Location 6)
Microstrain
Date

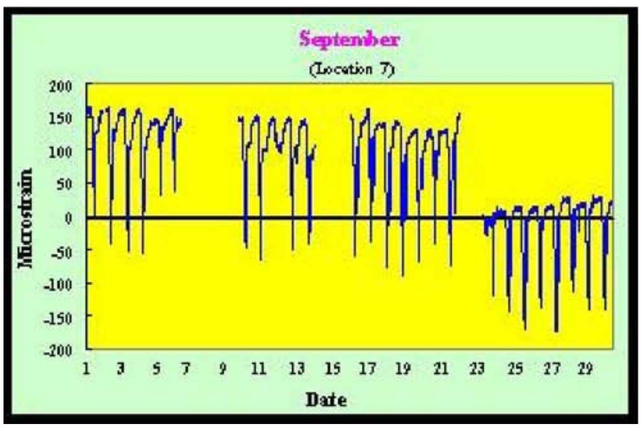
Location 7

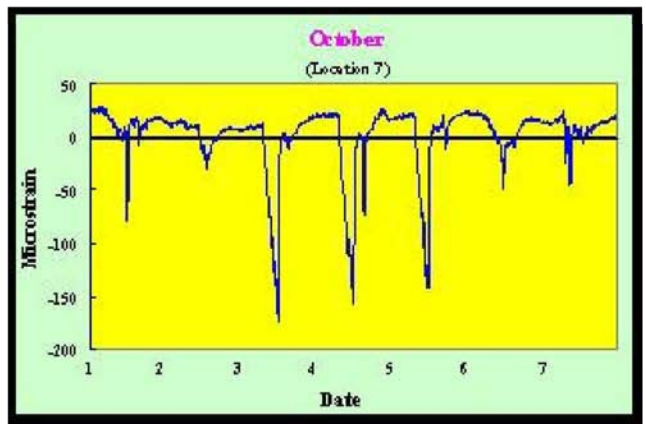

May
(Location 7)
Microstrain
Date


June
(Location 7)
Microstrain
Date

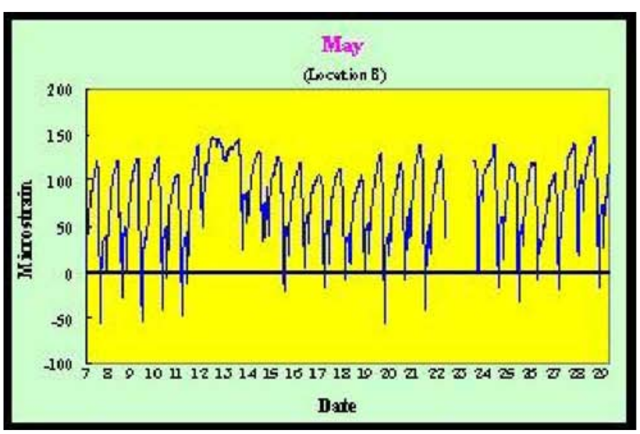

July
(Location 7)
Microstrain
Date

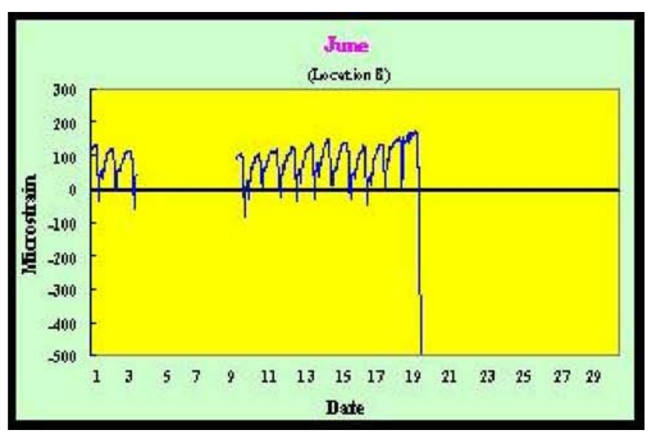

August
(Location 7)
Microstrain
Date


September
(Location 7)
Microstrain
Date

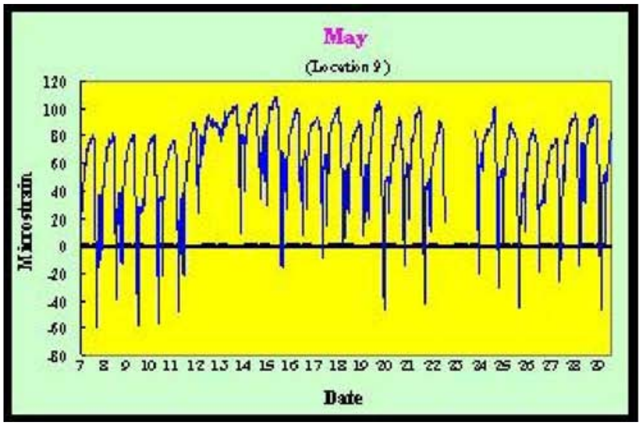

October
(Location 7)
Microstrain
Date

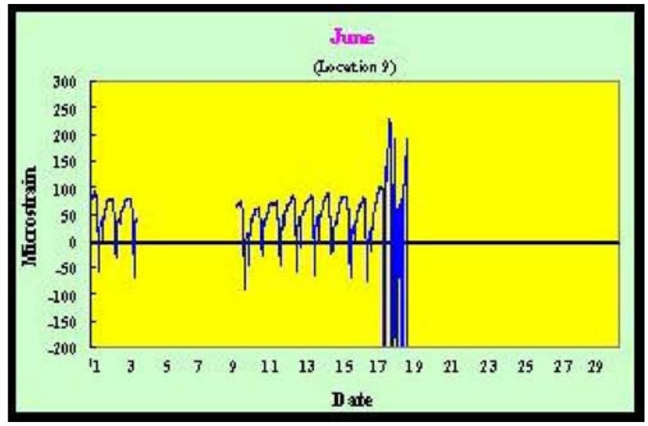
Location 8


May
(Location 8)
Microstrain
Date

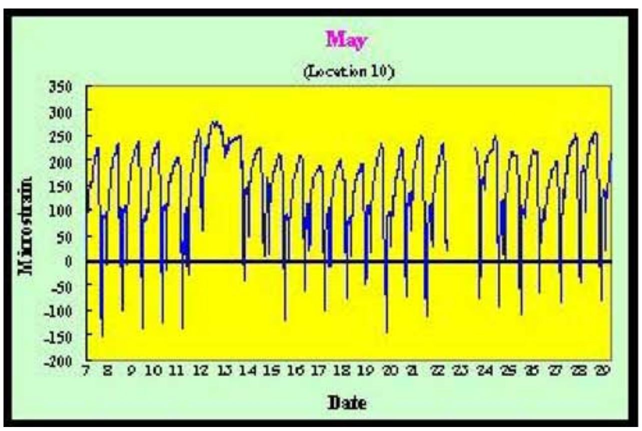

June
(Location 8)
Microstrain
Date

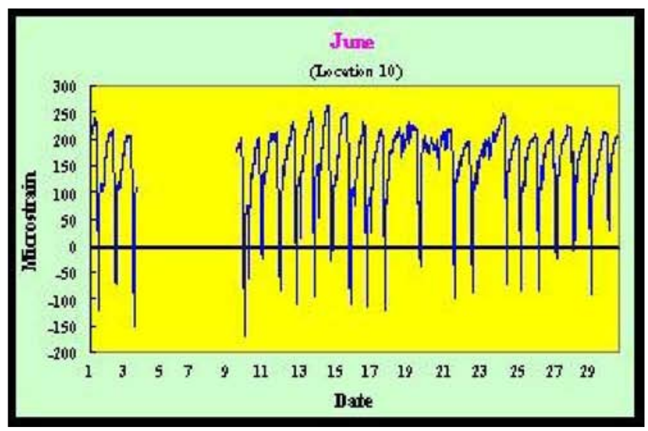
Location 9

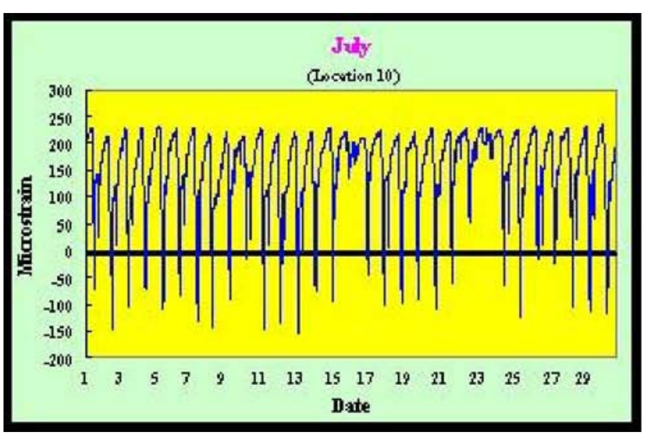


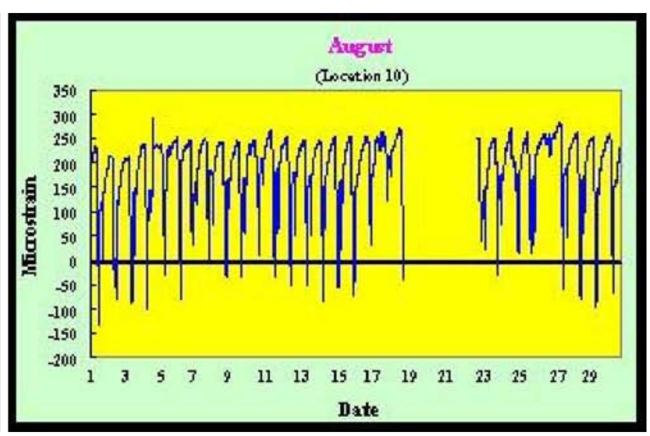


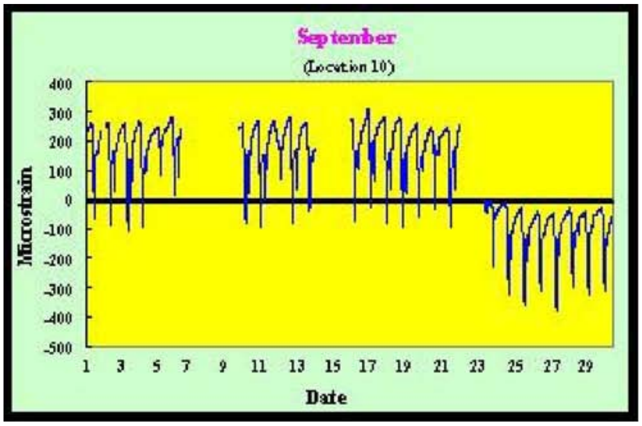
Location 10

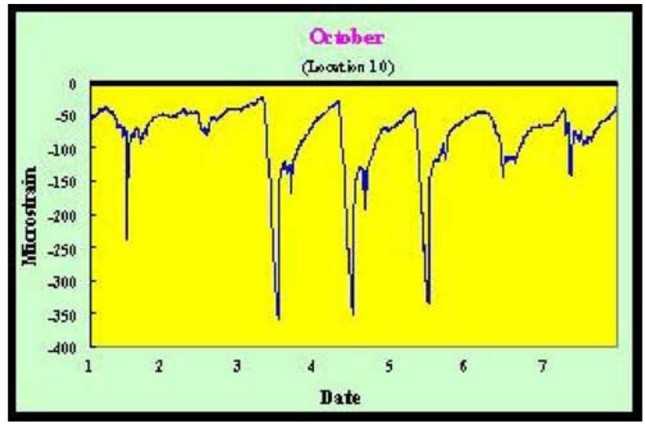




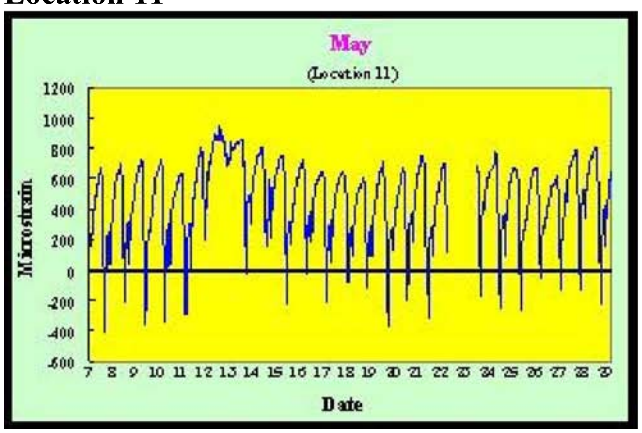


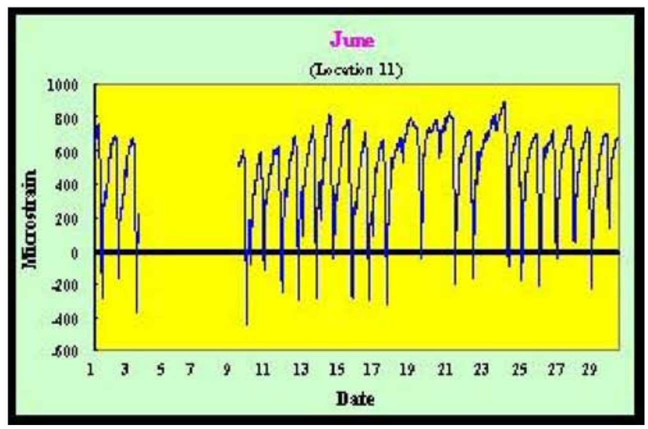


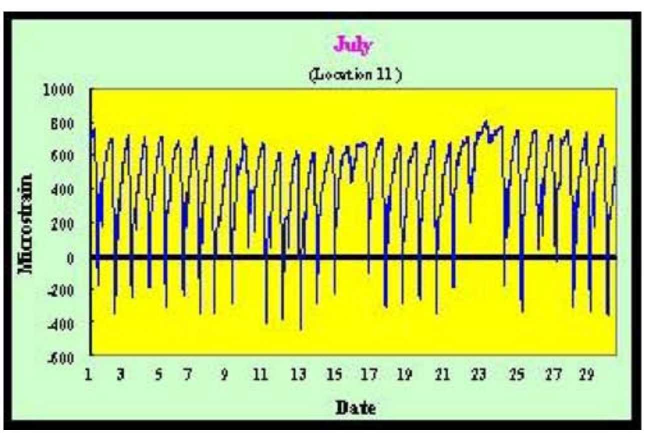

September
(Location 10)
Microstrain
400
300
200
100
0
-100
-200
-300
-400
-500
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Date

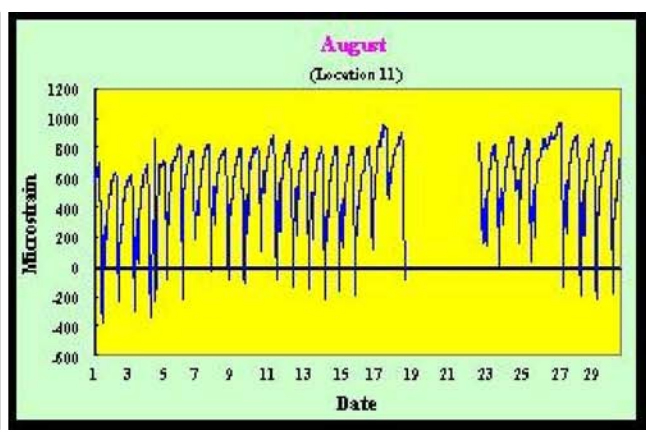

October
(Location 10)
Microstrain
0
-50
-100
-150
-200
-250
-300
-350
-400
1 2 3 4 5 6 7
Date

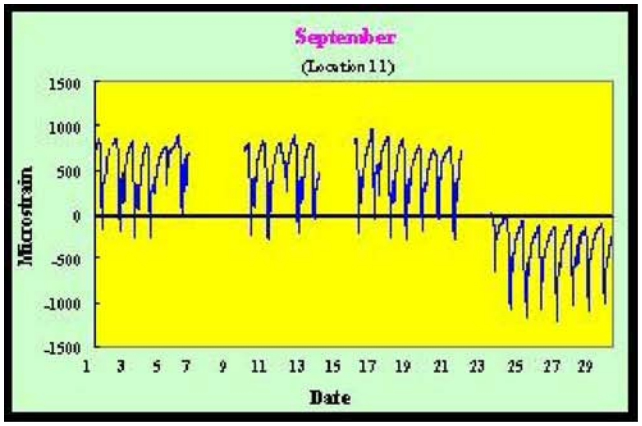
Location 11

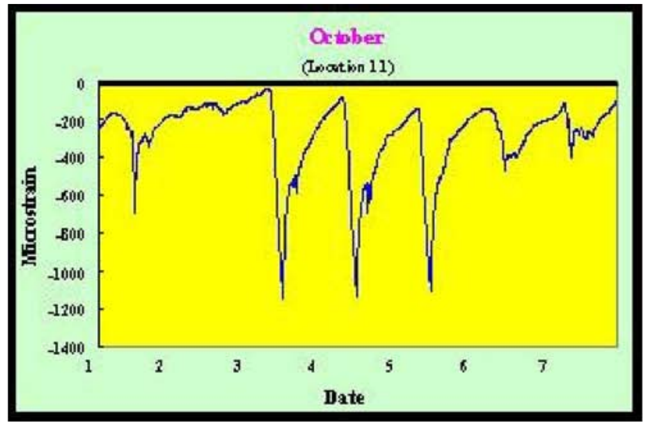

May
(Location 11)
Microstrain
1200
1000
800
600
400
200
0
-200
-400
-600
Date


June
(Location 11)
Microstrain
1000
800
600
400
200
0
-200
-400
-600
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Date

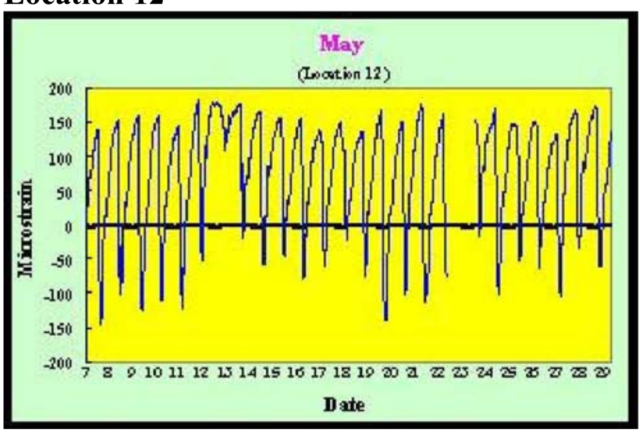

July
(Location 11)
Microstrain
1000
800
600
400
200
0
-200
-400
-600
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Date

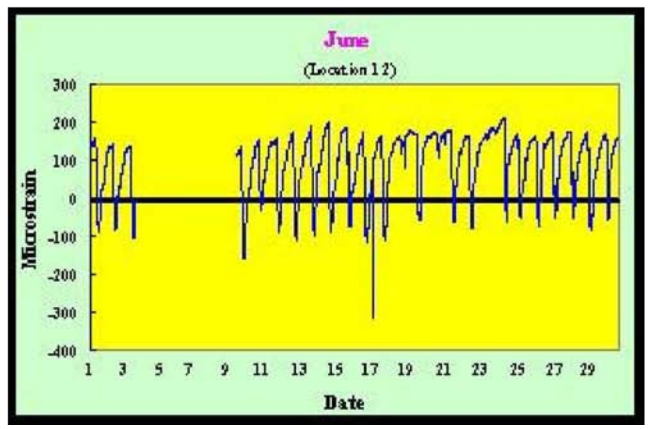

August
(Location 11)
Microstrain
1200
1000
800
600
400
200
0
-200
-400
-600
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Date

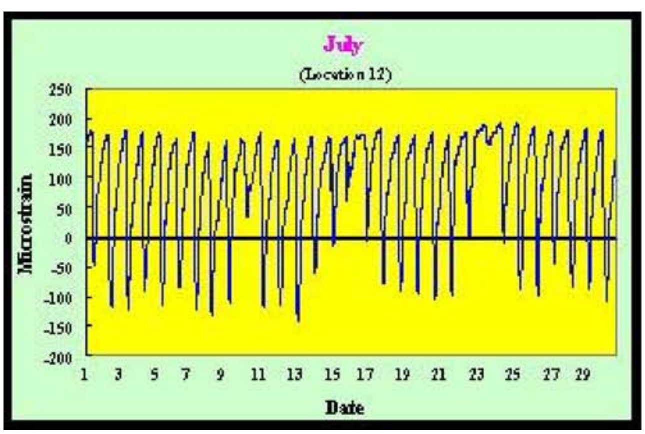

September
(Location 11)
Microstrain
Date

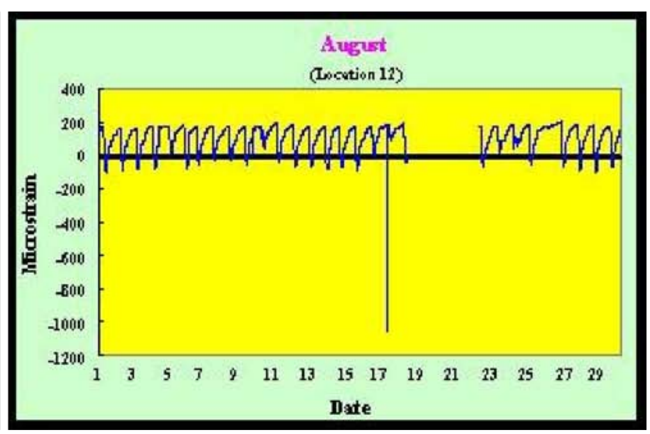

October
(Location 11)
Microstrain
Date

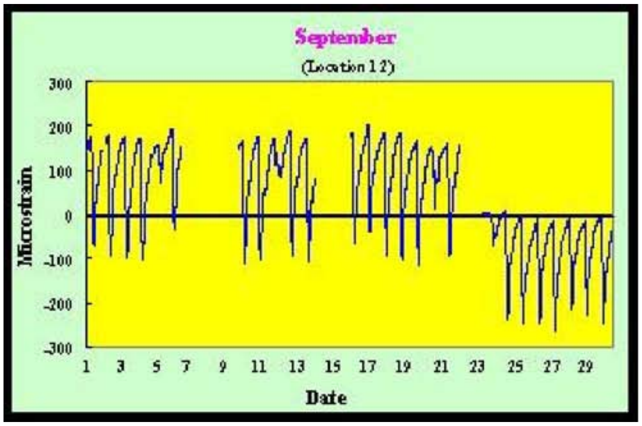
Location 12

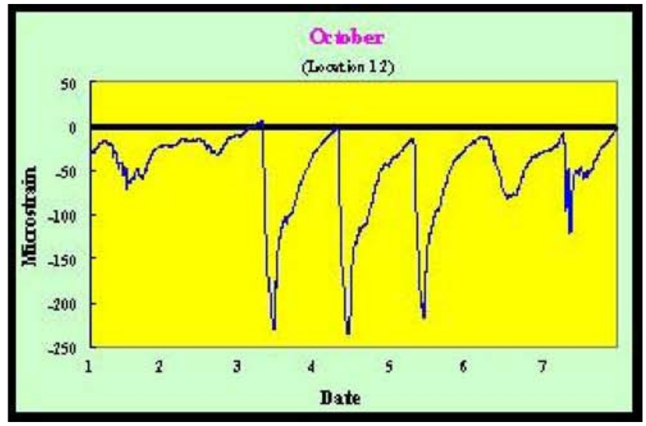

May
(Location 12)
Microstrain
Date


June
(Location 12)
Microstrain
Date

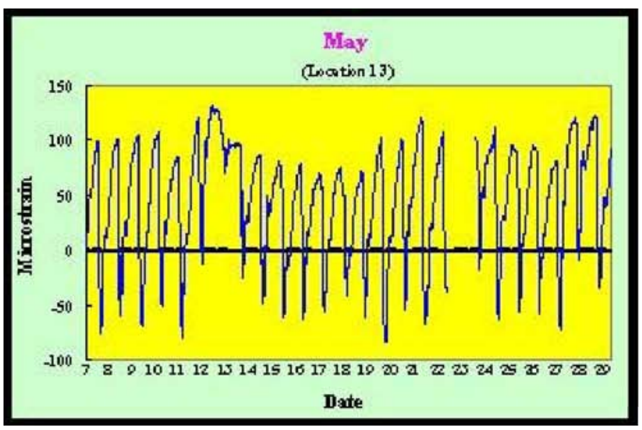

July
(Location 12)
Microstrain
Date

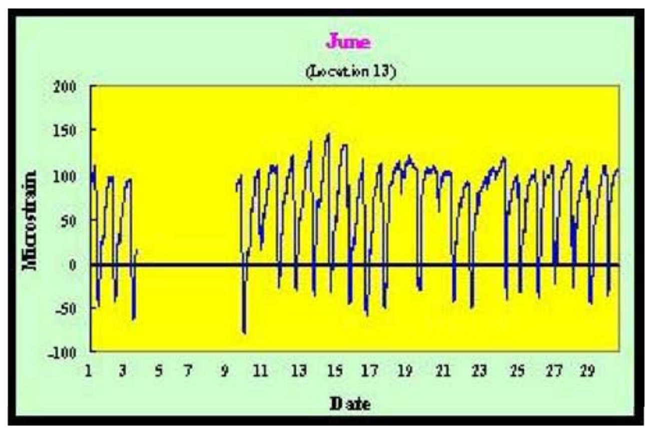

August
(Location 12)
Microstrain
Date

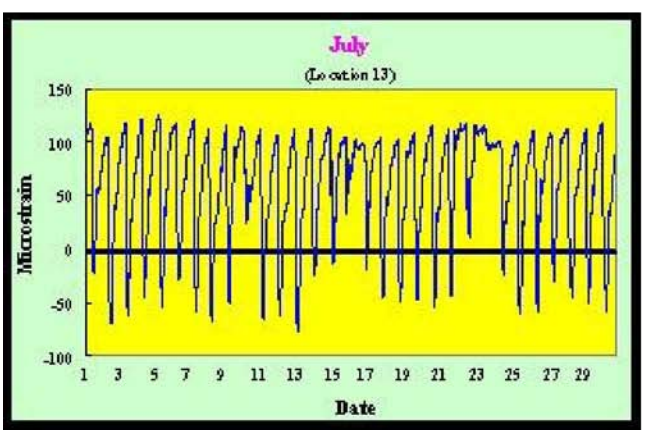

September
(Location 12)
Microstrain
Date

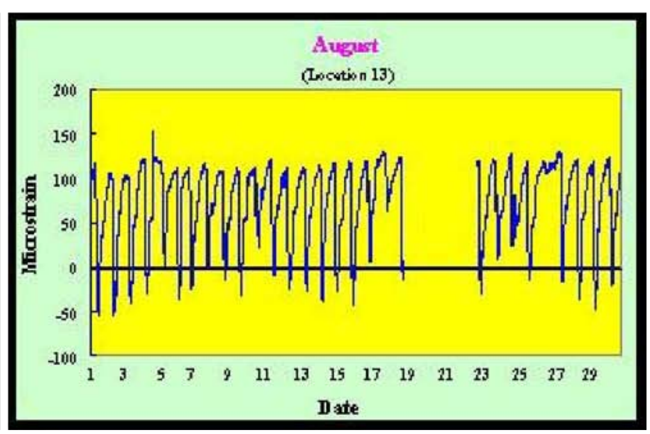

October
(Location 12)
Microstrain
Date

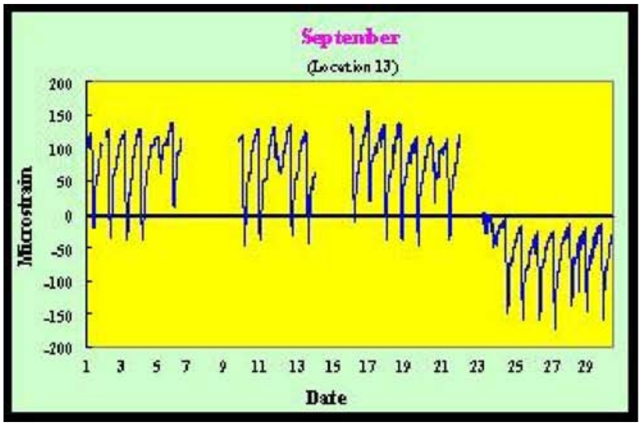
Location 13

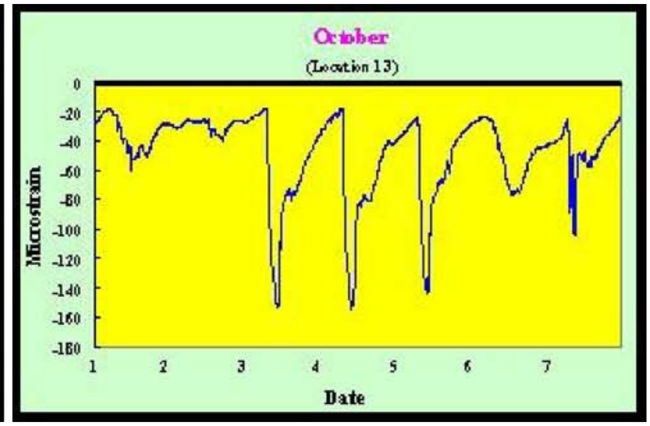

May
(Location 13)
Microstrain
Date


June
(Location 13)
Microstrain
Date

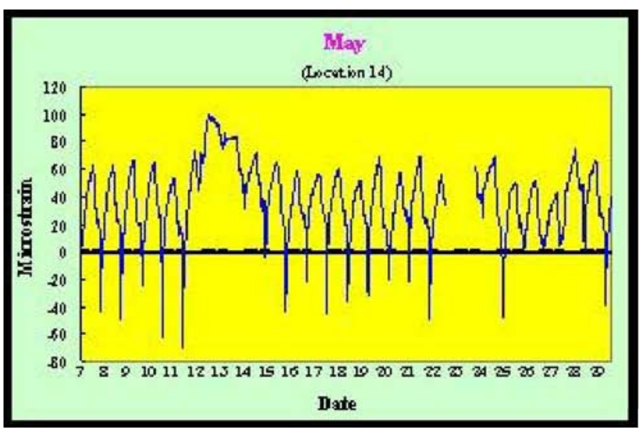

July
(Location 13)
Microstrain
Date

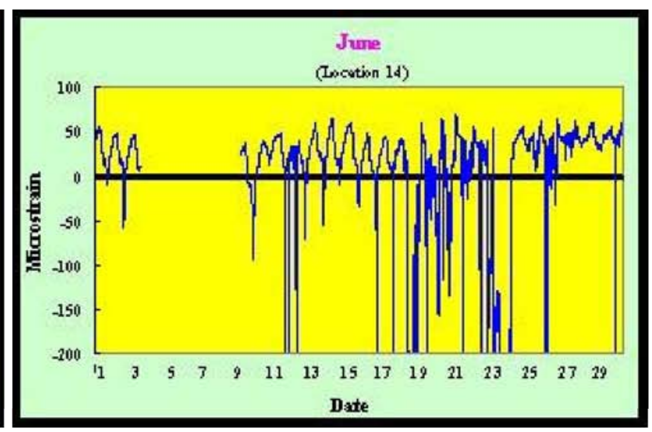

August
(Location 13)
Microstrain
Date

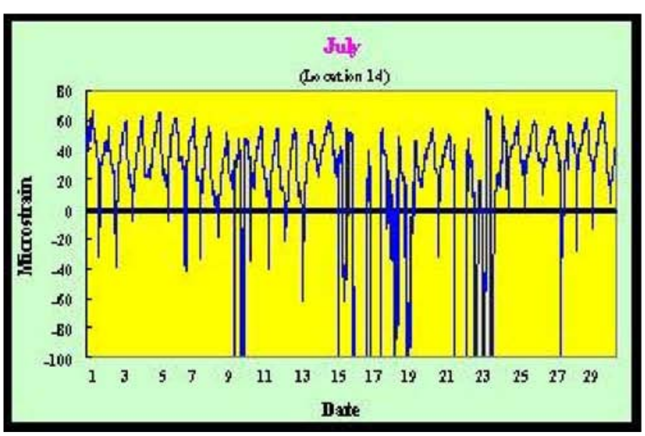

September
(Location 13)
Microstrain
Date

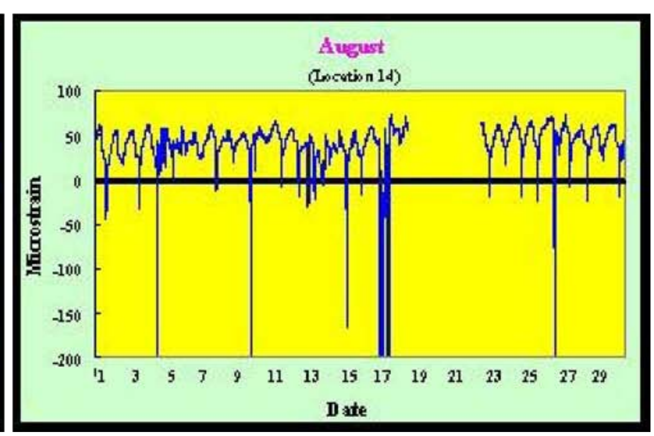

October
(Location 13)
Microstrain
Date

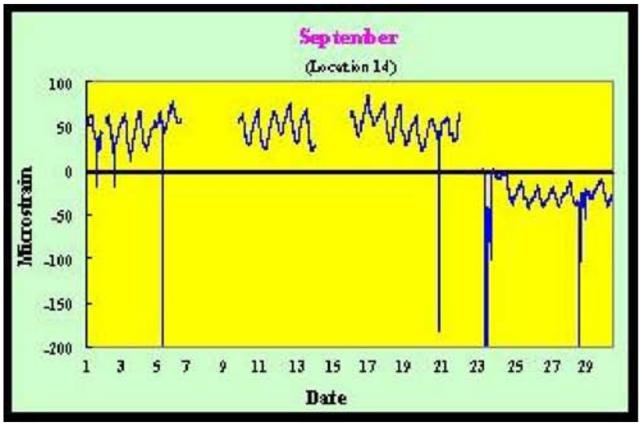
Location 14

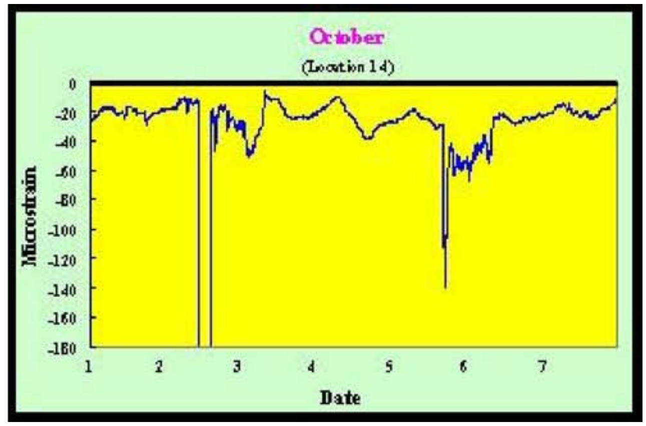

May
(Location 14)
Microstrain
Date


June
(Location 14)
Microstrain
Date

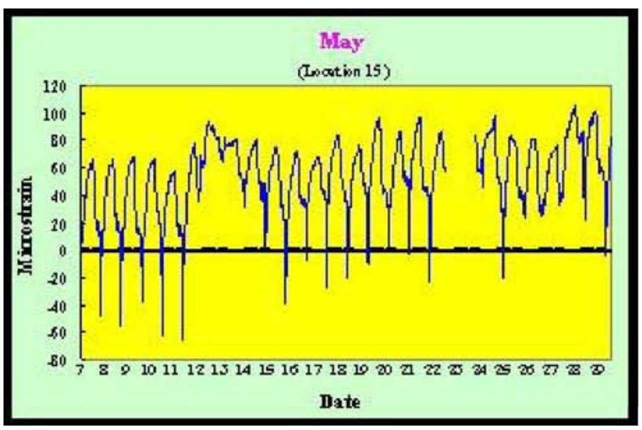

July
(Location 14)
Microstrain
Date

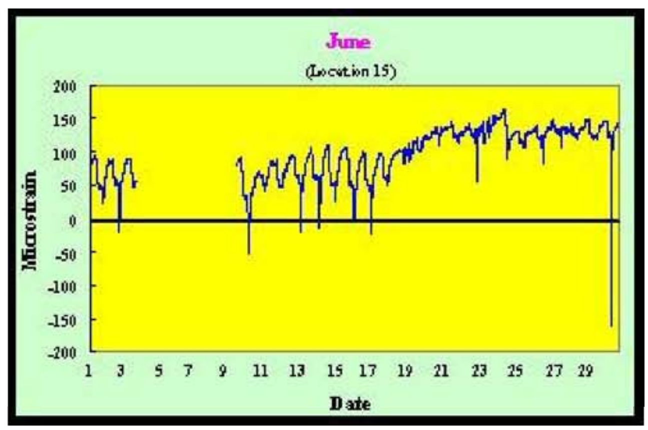

August
(Location 14)
Microstrain
Date

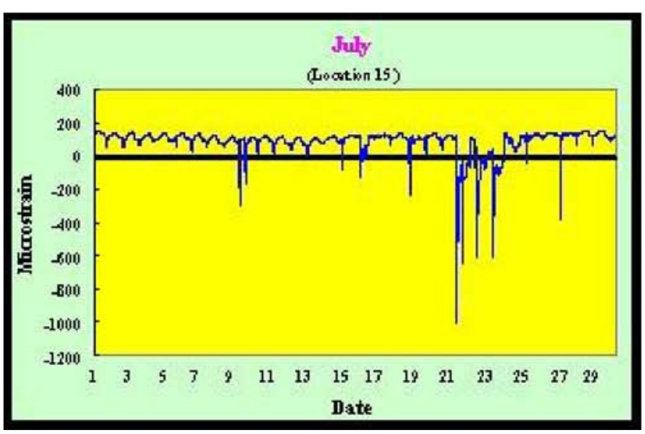

September
(Location 14)
Microstrain
Date

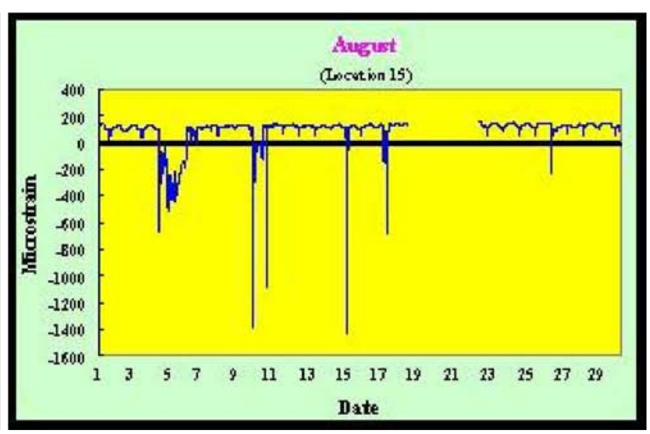

October
(Location 14)
Microstrain
Date

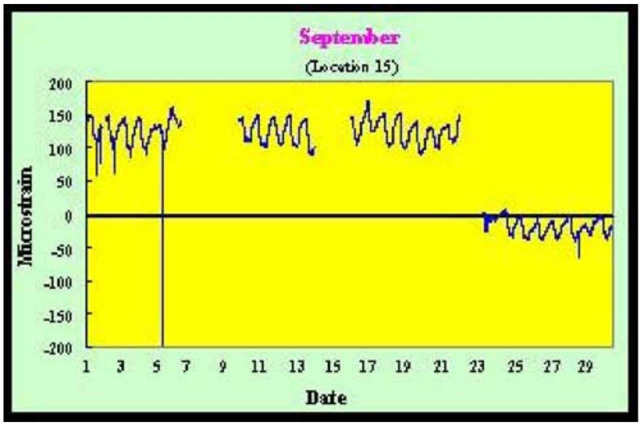
Location 15

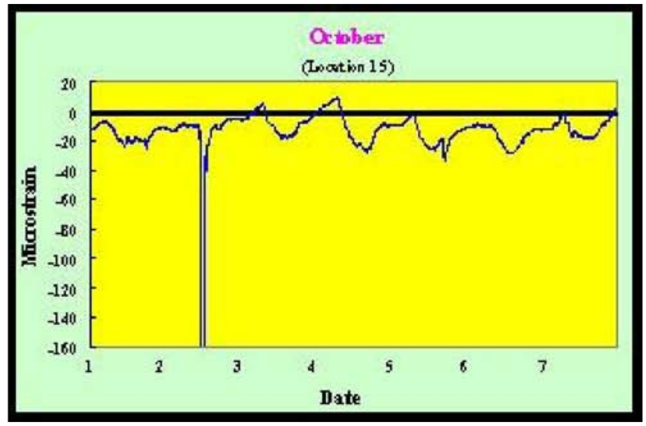

May
(Location 15)
Microstrain
Date


June
(Location 15)
Microstrain
Date

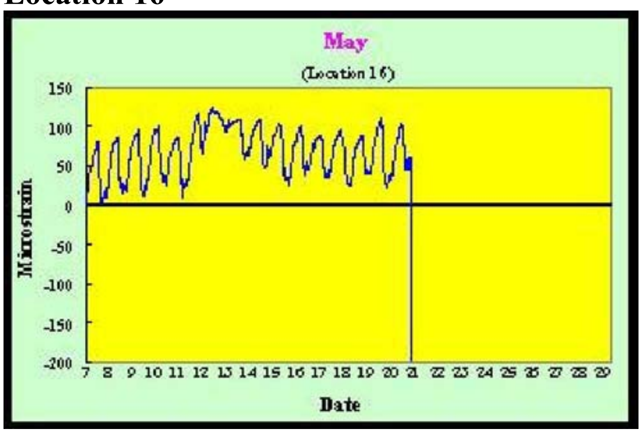

July
(Location 15)
Microstrain
Date


August
(Location 15)
Microstrain
Date

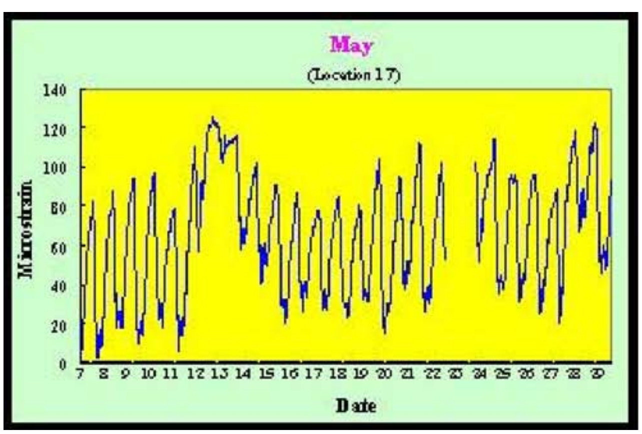


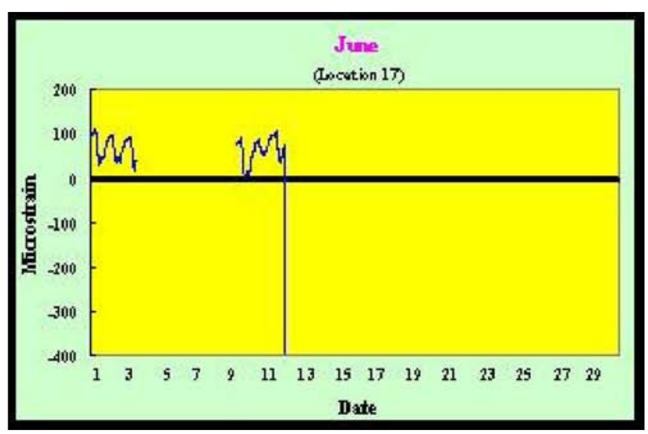


Location 16

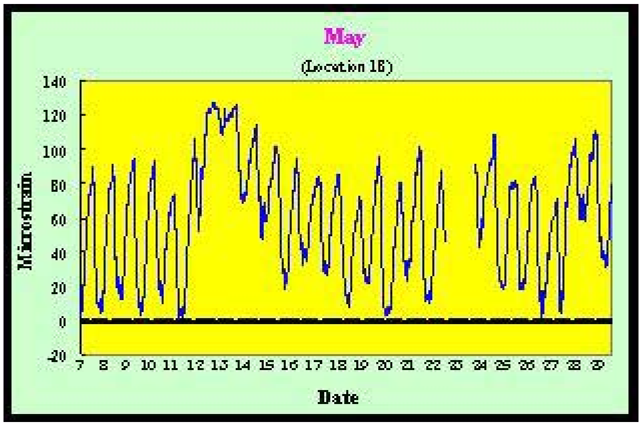


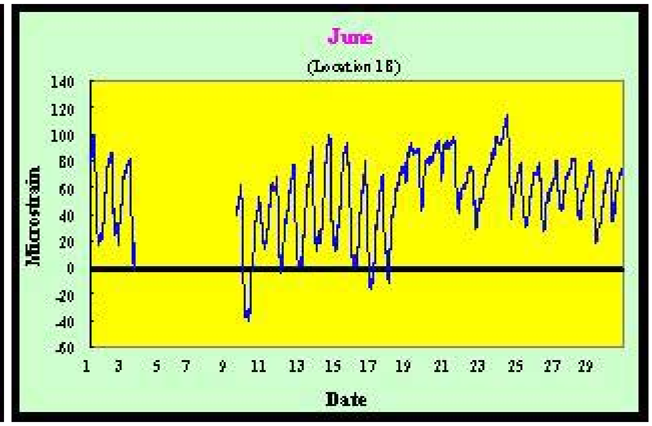
Location 17

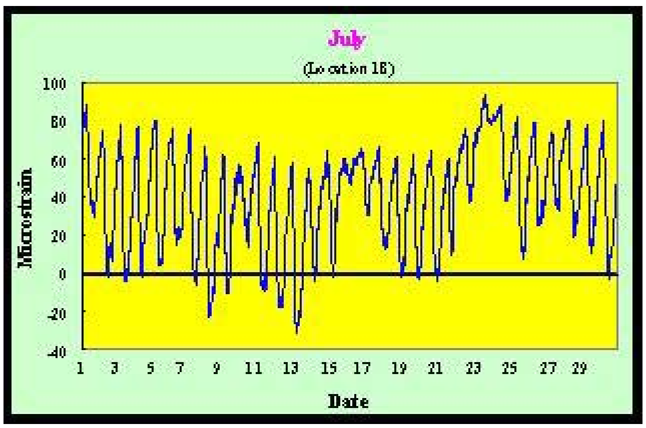


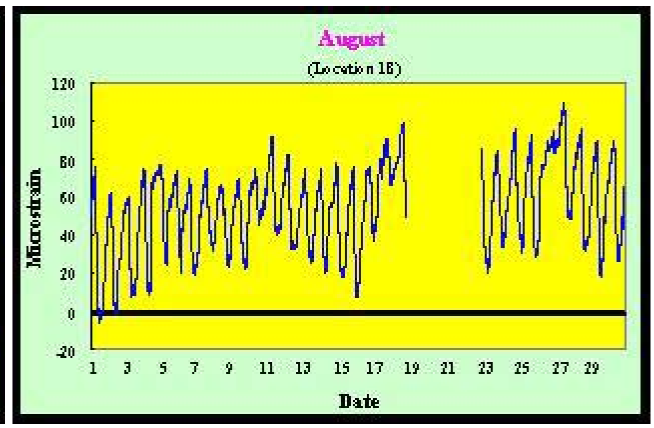


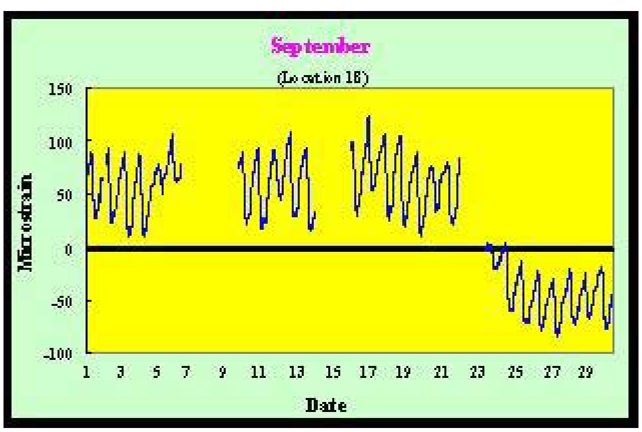
Location 18

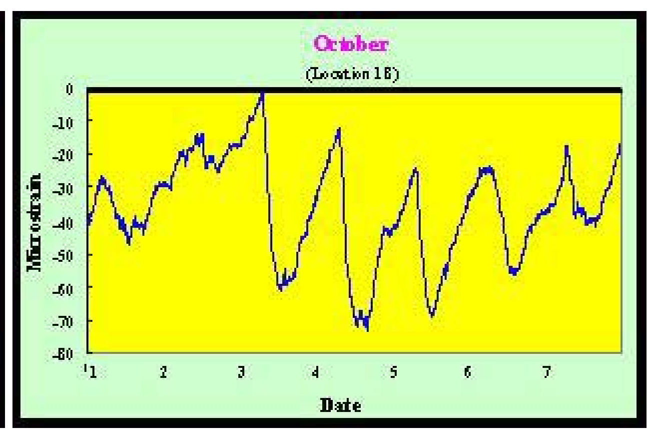

May
(Location 18)
Microstrain
Date


June
(Location 18)
Microstrain
Date


July
(Location 18)
Microstrain
Date


August
(Location 18)
Microstrain
Date


September
(Location 18)
Microstrain
Date


October
(Location 18)
Microstrain
Date