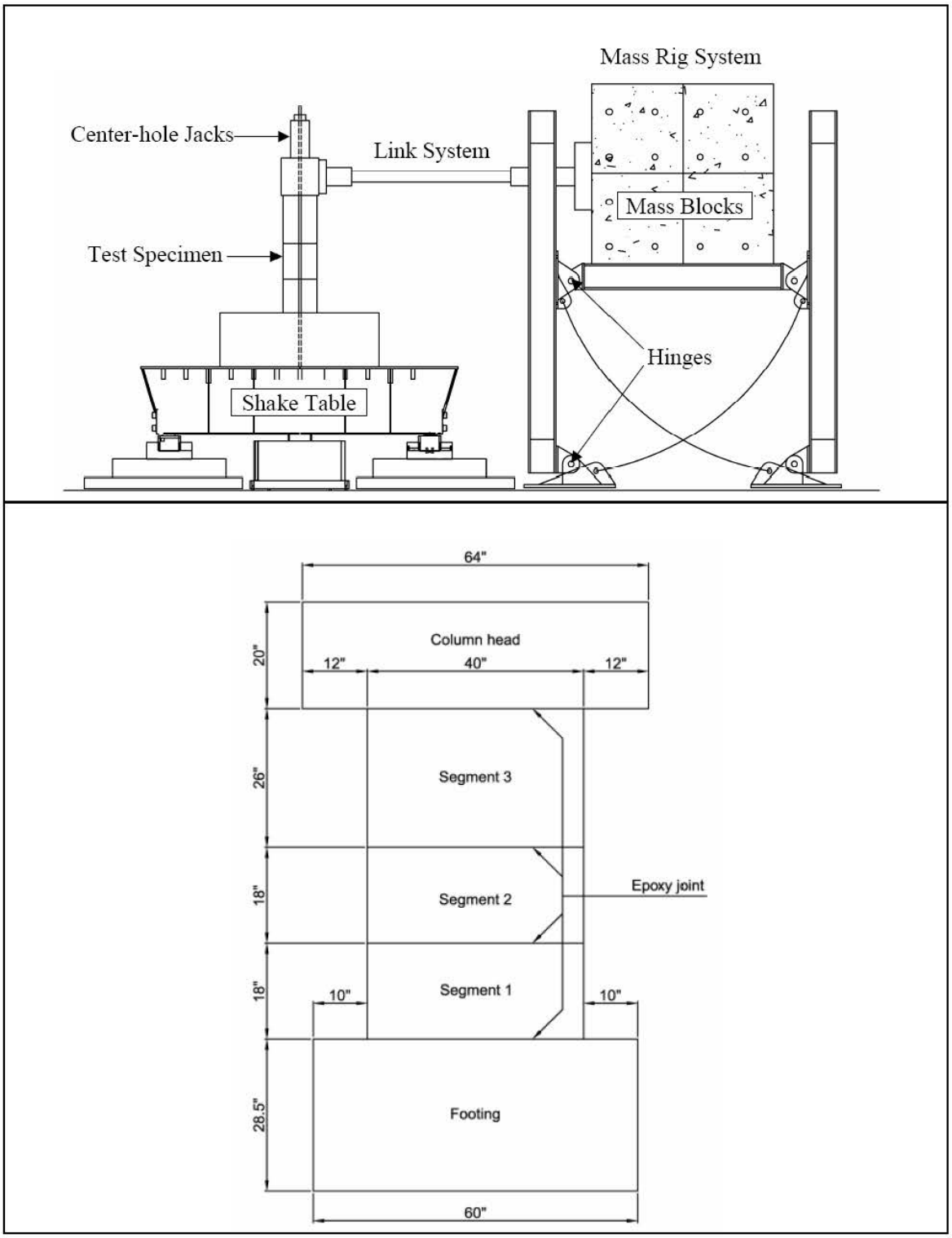


Fig. 1-3. Post-Tensioned Hollow Precast Columns [Yamashita and Sanders,2006]

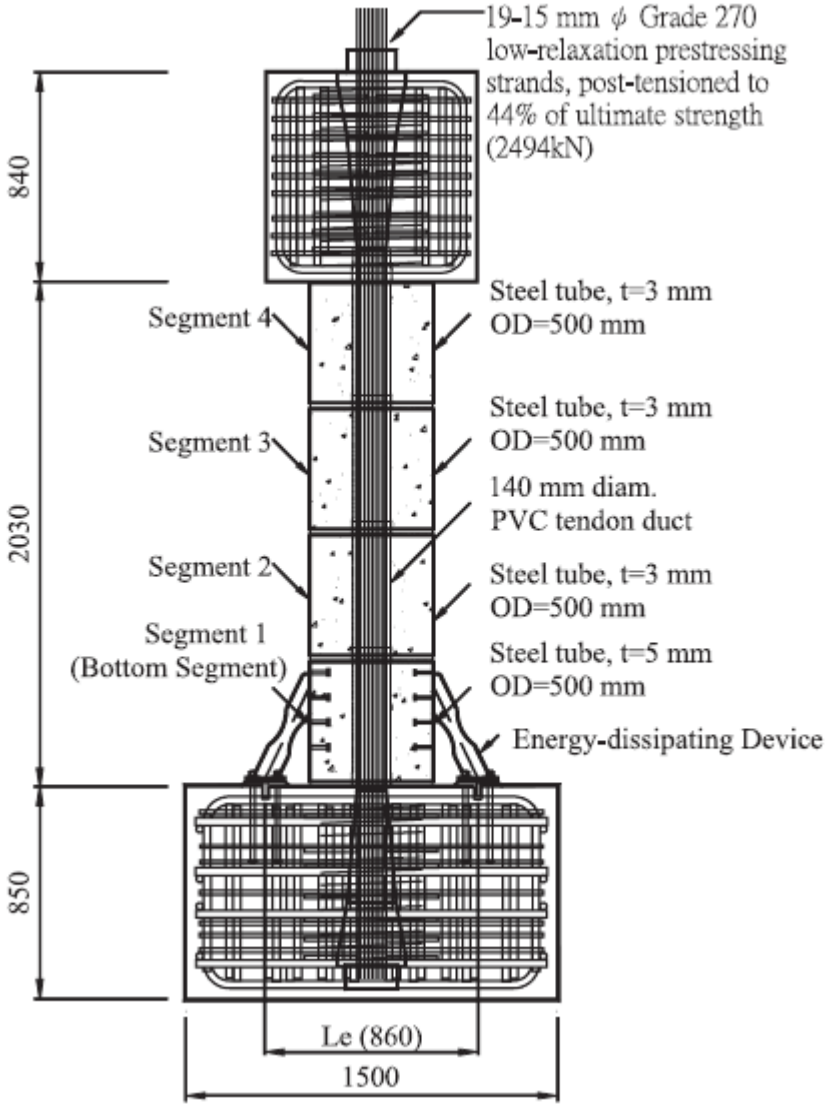


Fig. 1-4. Precast Segmental Column with Energy Dissipating Device [Chou and Chen,2005]

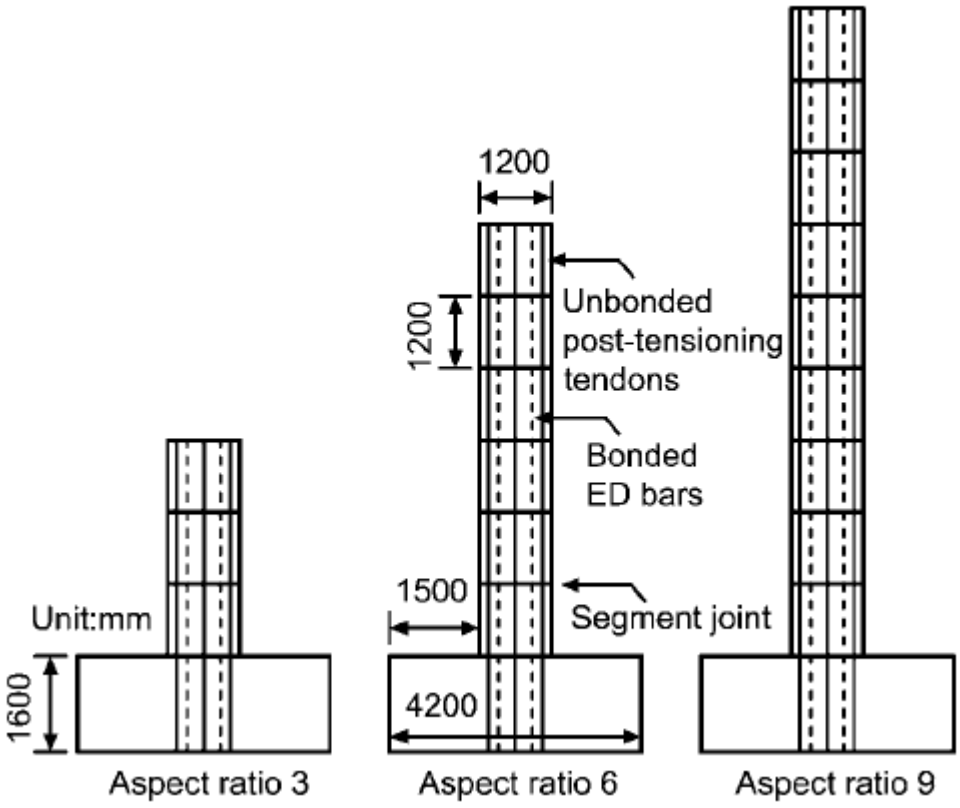


Fig. 1-5. Precast Segmental Column with Unbonded Post-Tensioning System [Ou, et al, 2007]

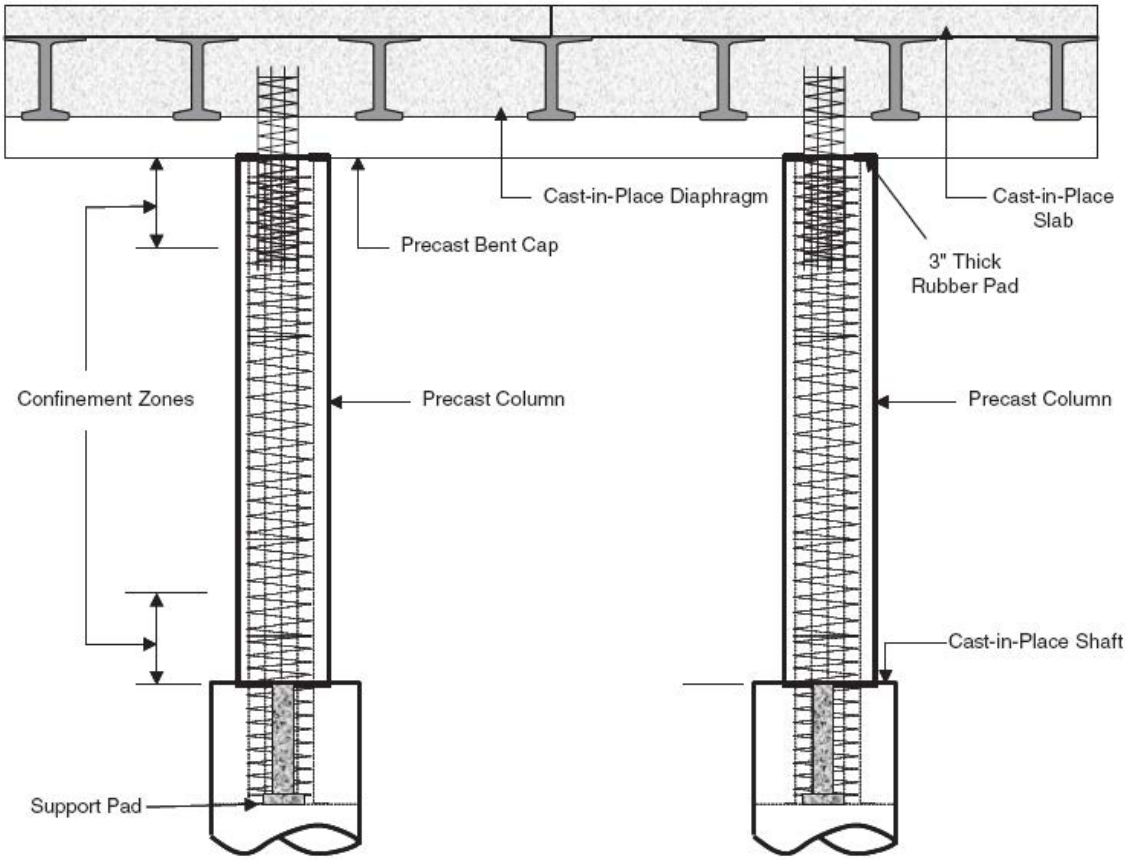


Fig. 1-6. Precast Seismic Resistant Bridge [Khaleghi,2005]

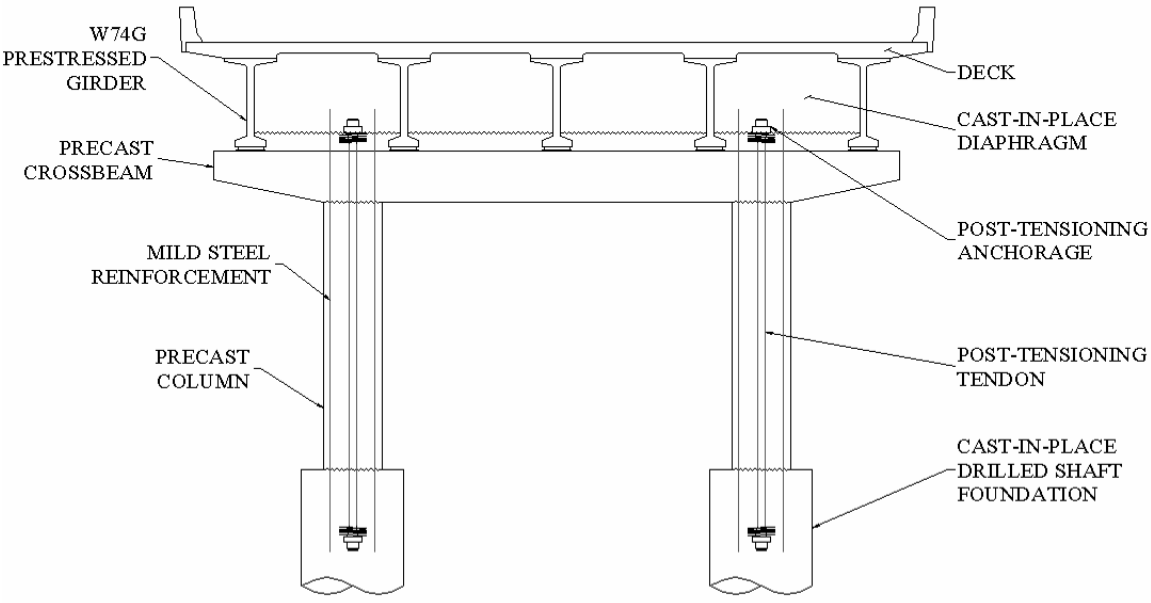


Fig. 1-7. Hybrid Precast Concrete Pier System, [Hieber, et al, 2005]

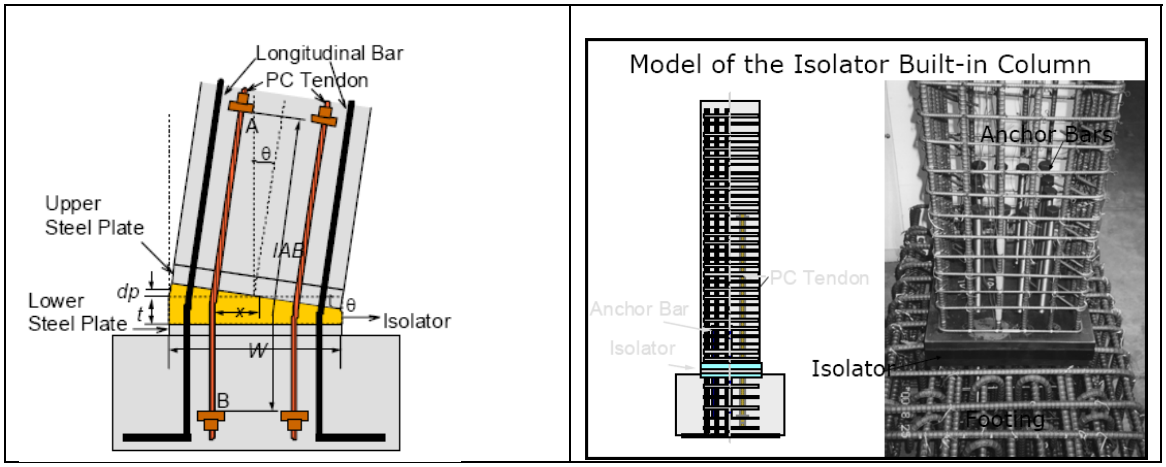


Fig. 1-8. Isolator Built in Column Tested By Kawashima and Nagai, (2002)

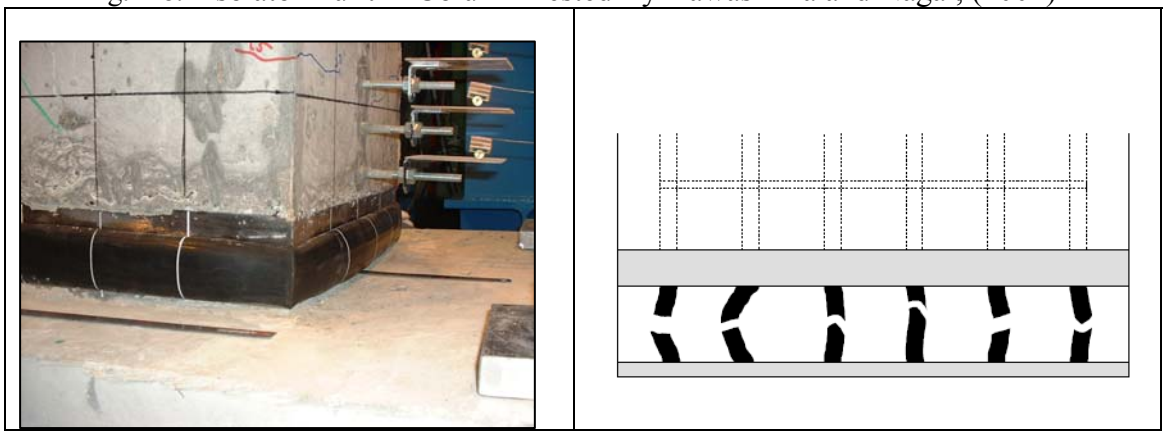


Fig. 1-9. Longitudinal Bars Buckling in Rubber Pad Unit [Kawashima and Watanabe, 2006]

Fig. 1-10. PVA Fibers in ECC Material [Wang and Saiidi, 2005]

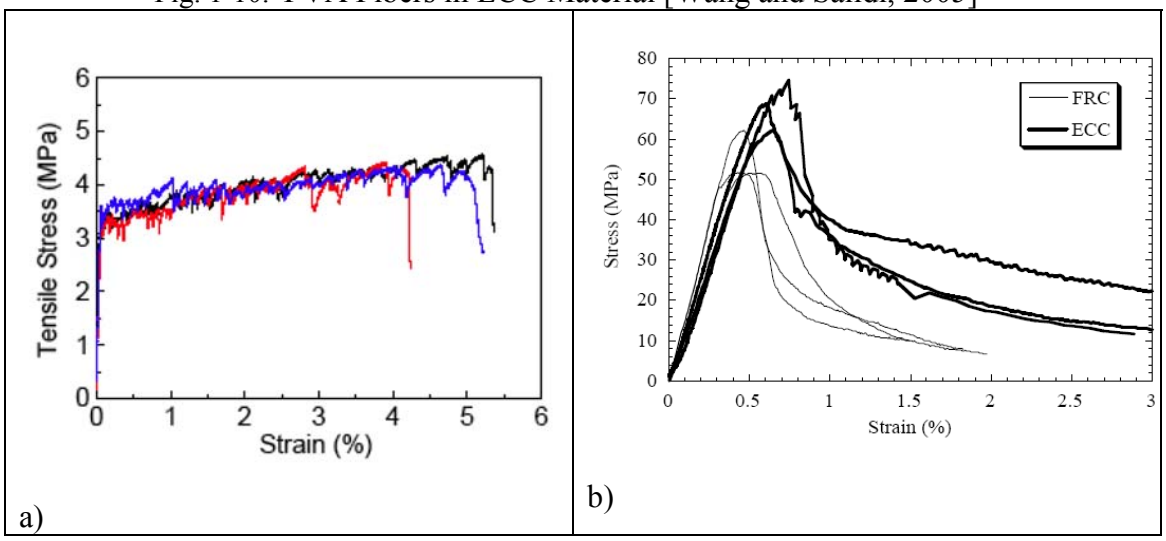


Fig. 1-11. a)Uniaxial Tensile Stress-Strain Curves of ECC b) Uniaxial Compressive Stress-Strain Curves of ECC [Li, 1998]

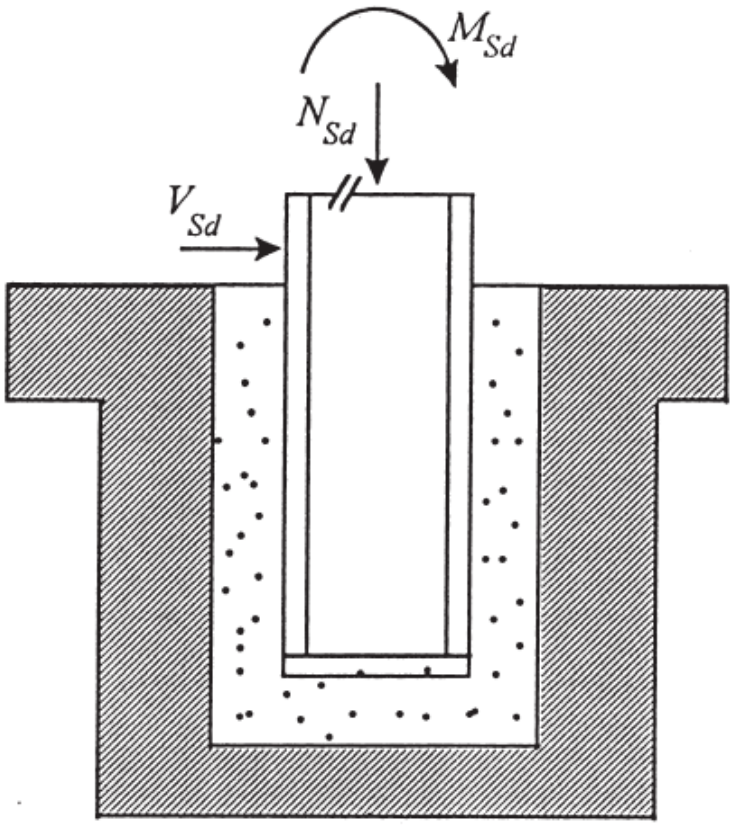


Fig. 1-12. Calculation of Embedded Length by Pertold, et al (2000b)

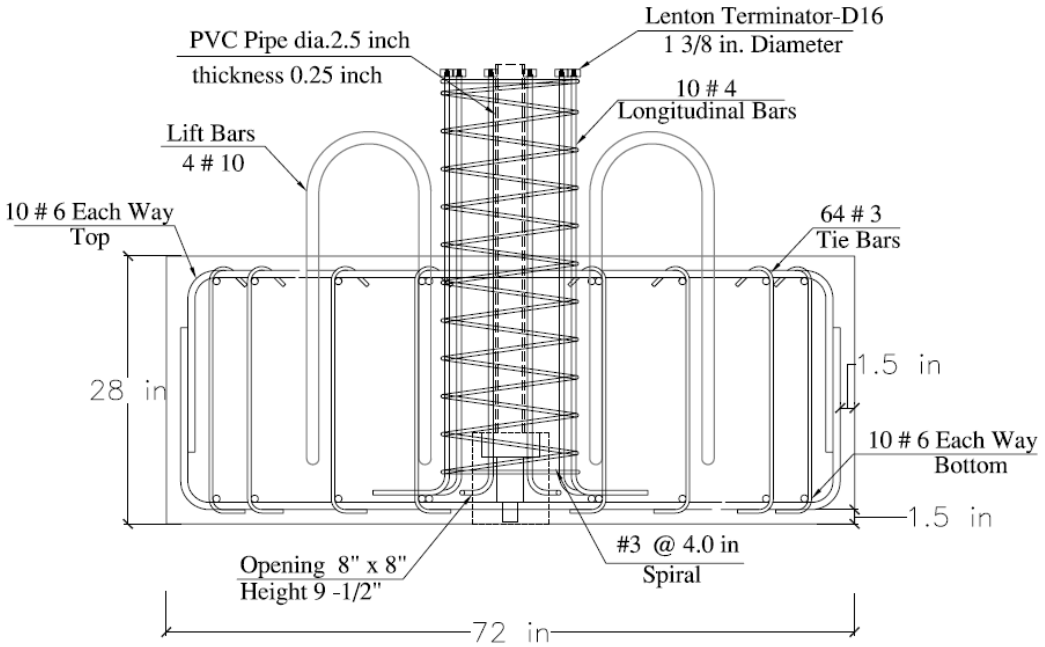


Fig. 2-1. Segmental Columns Footing Detail

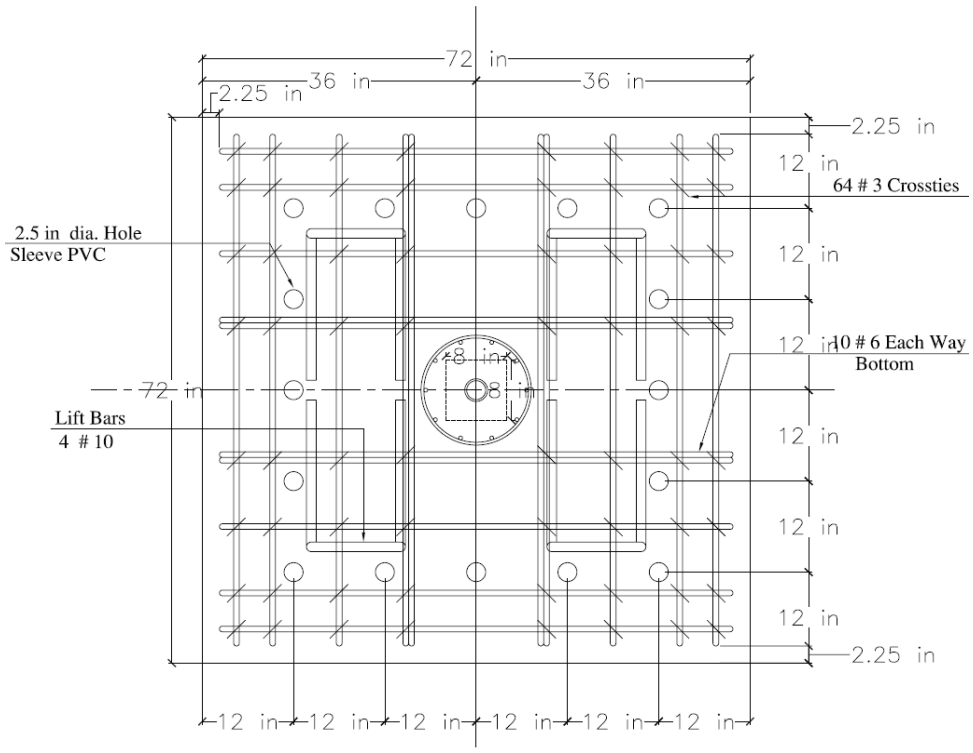


Fig. 2-2. Segmental Columns Footing Plan View Detail

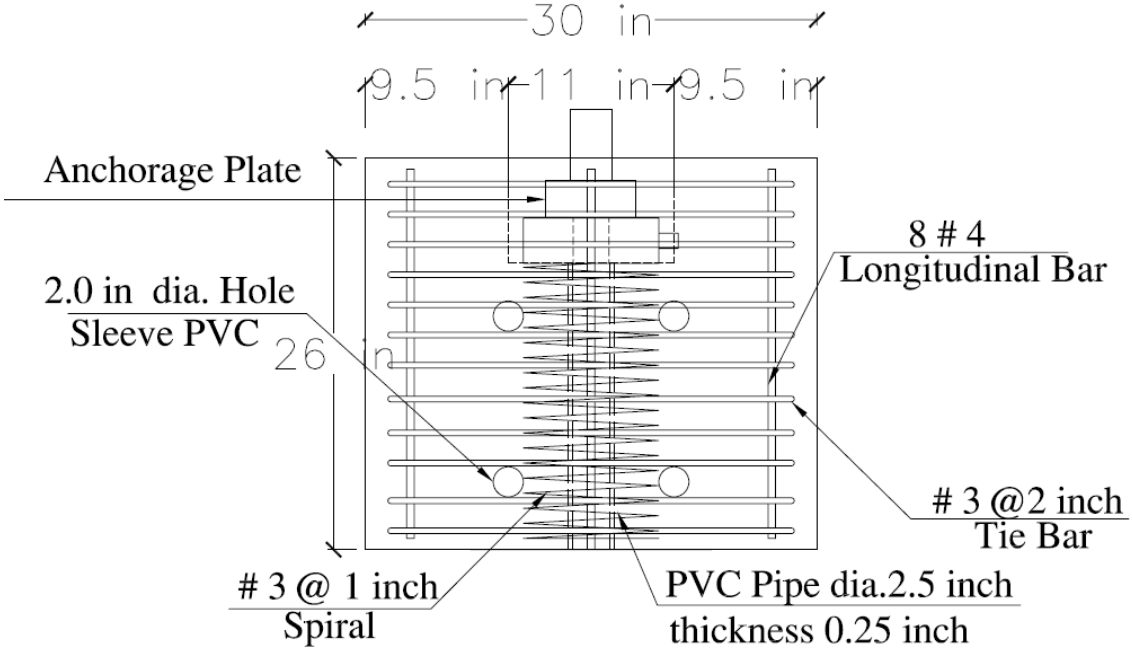


Fig. 2-3. Segmental Columns Head Detail

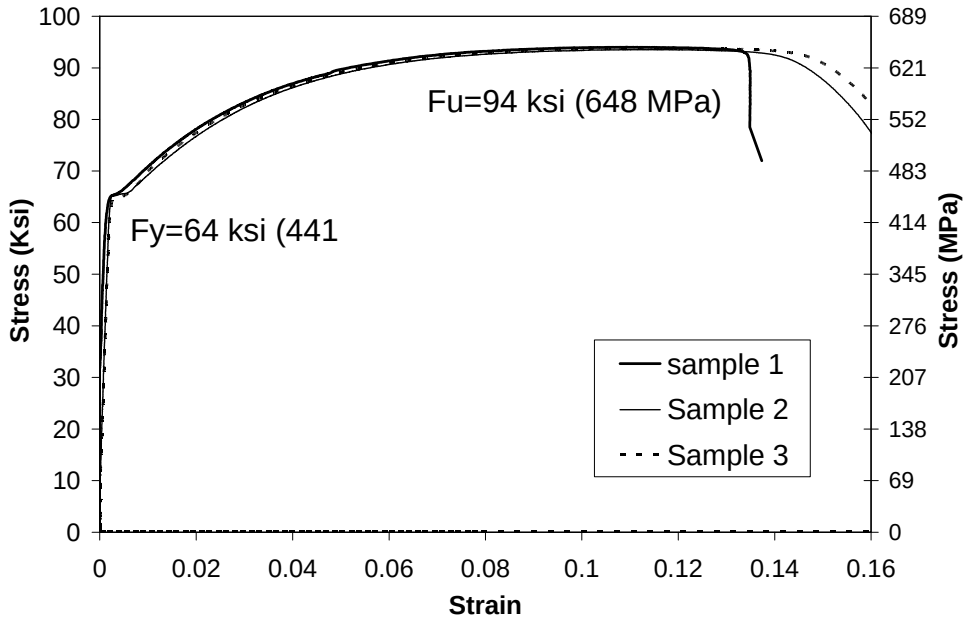


Fig. 2-4. Stress-Strain Behavior of #4 Bars in SC2,SF-2, and SE-2

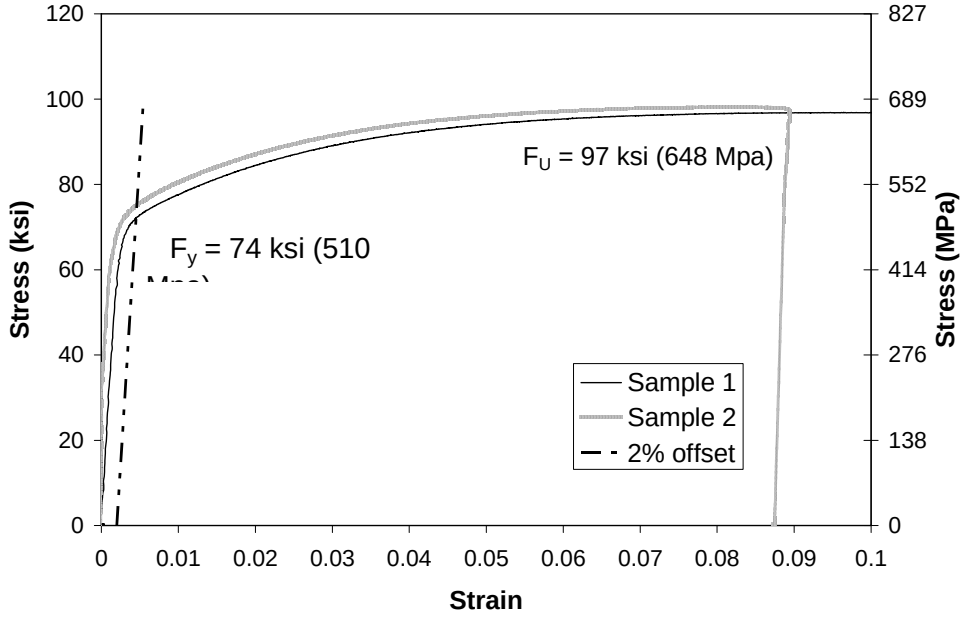


Fig. 2-5. Stress-Strain Behavior of #5 Bars in SBR-1

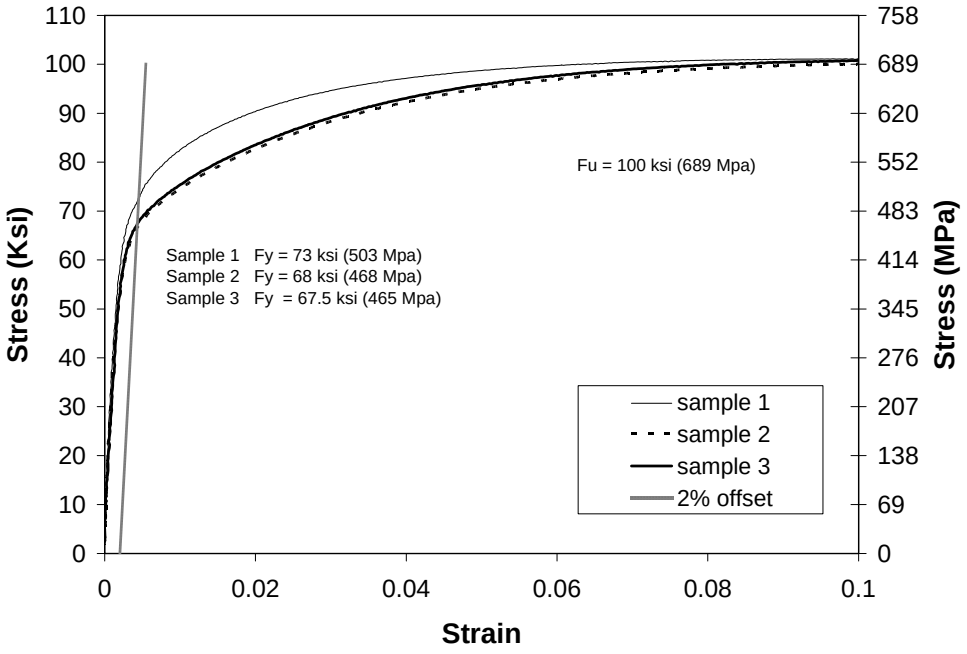


Fig. 2-6. Stress-Strain Behavior of #3 Bars in SC2,SF-2, and SE-2

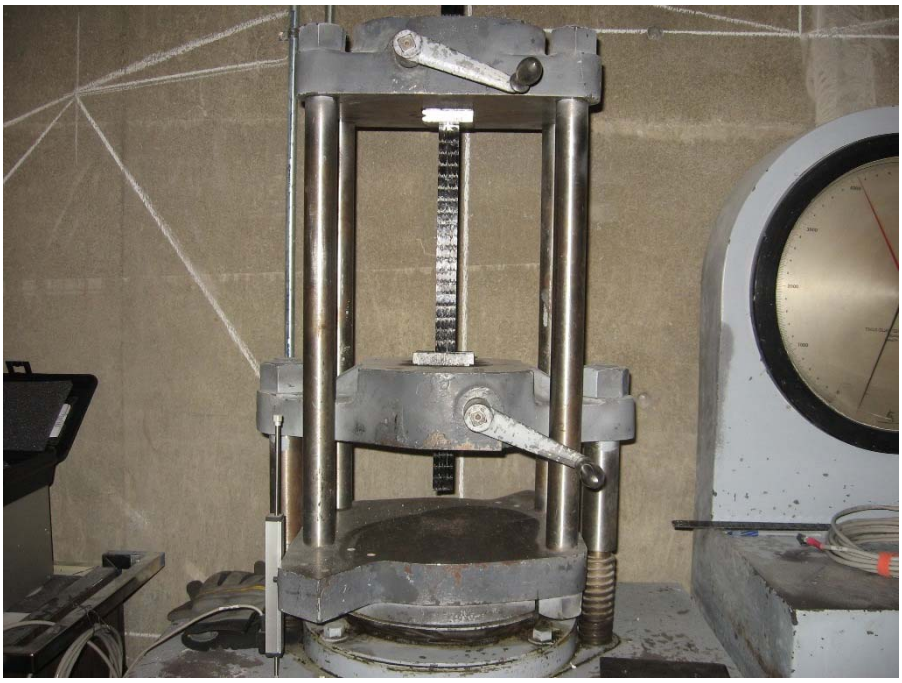


Fig. 2-7. FRP Coupon Testing

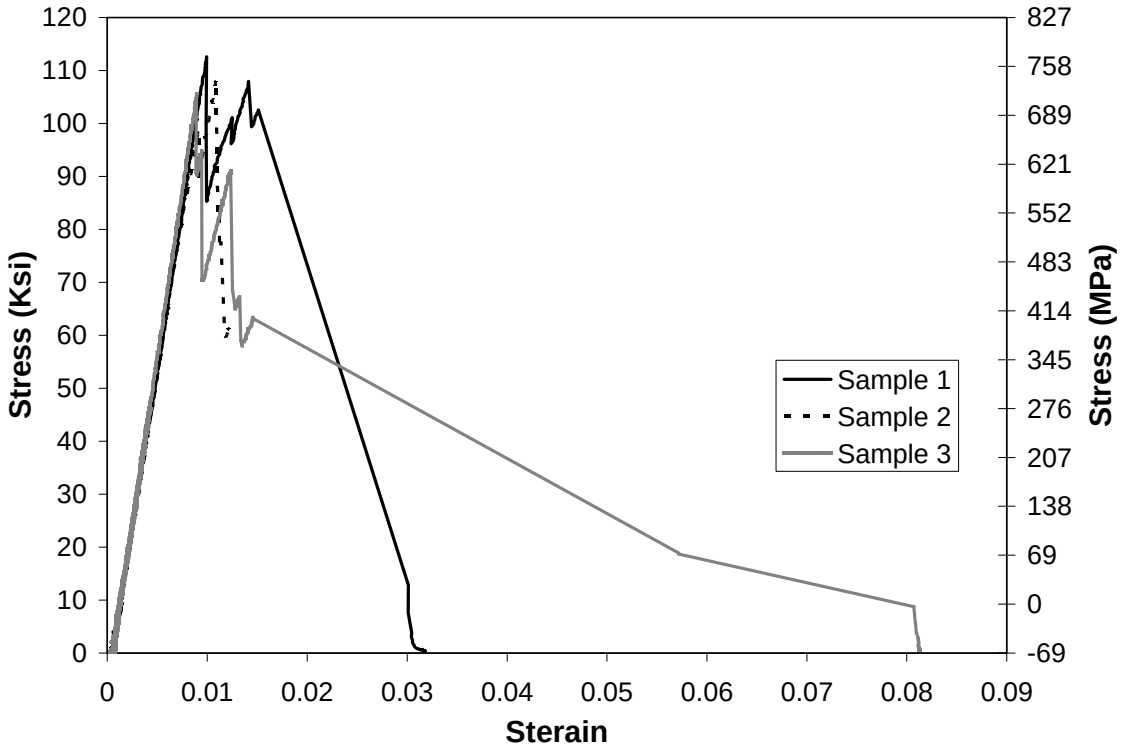
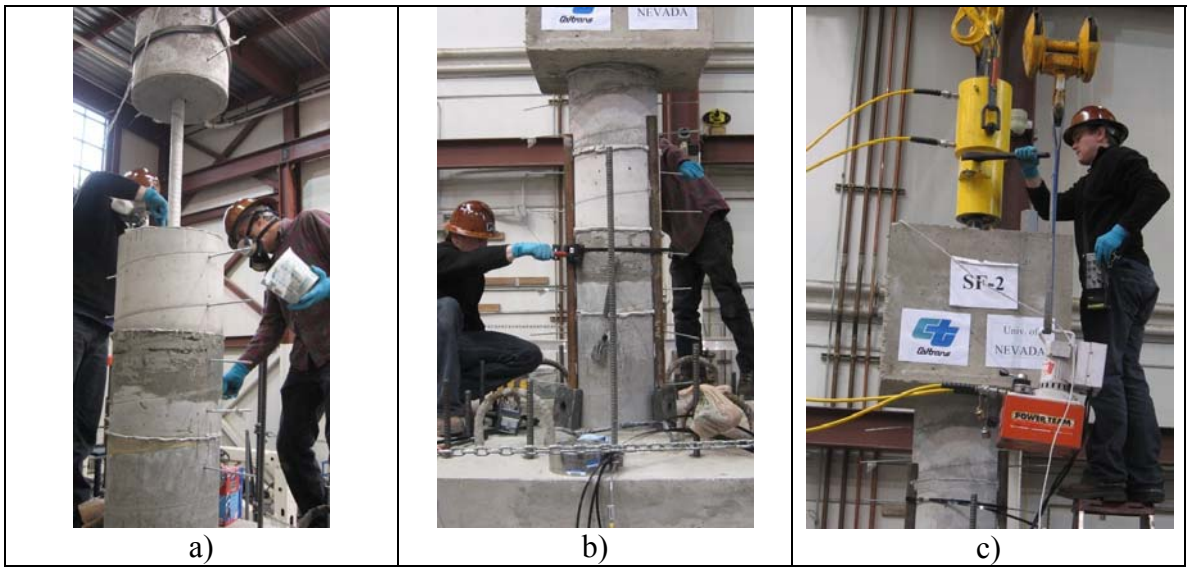


Fig. 2-8. Stress-Strain Relation for FRP (2 layers)



a) b) c)

Fig. 2-9. Columns Assembly, a) Setting the Segments, b) Adjusting the Segments, c) Post-Tensioning

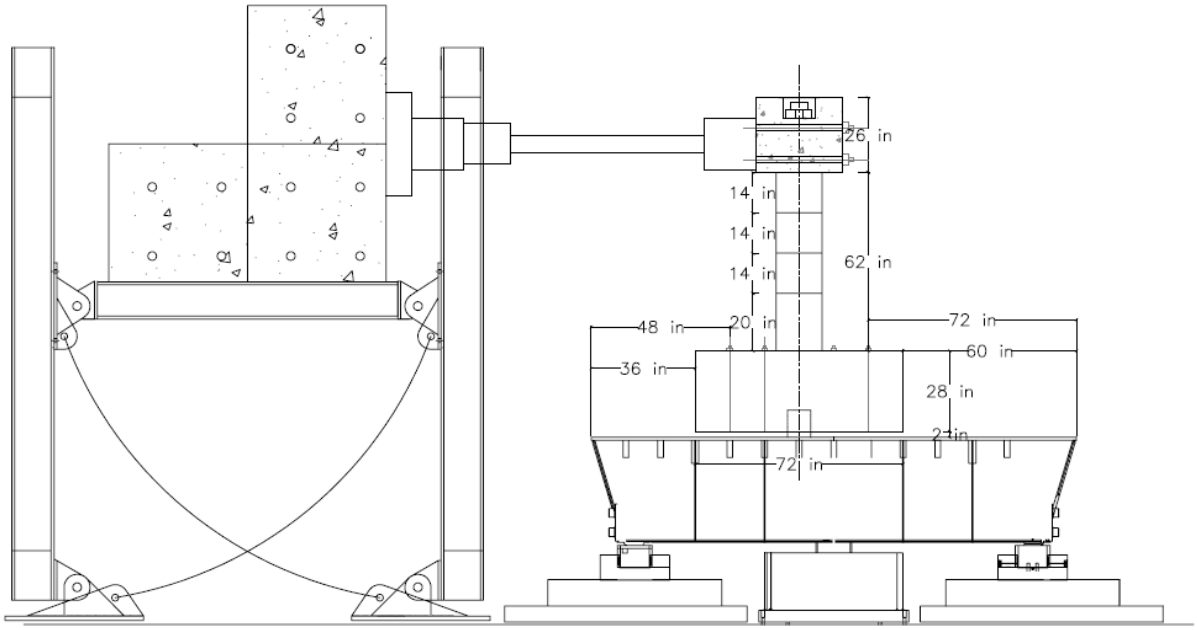


Fig. 2-10. Shake Table Test Set Up Geometry

Fig. 2-11. Shake Table Test Set Up

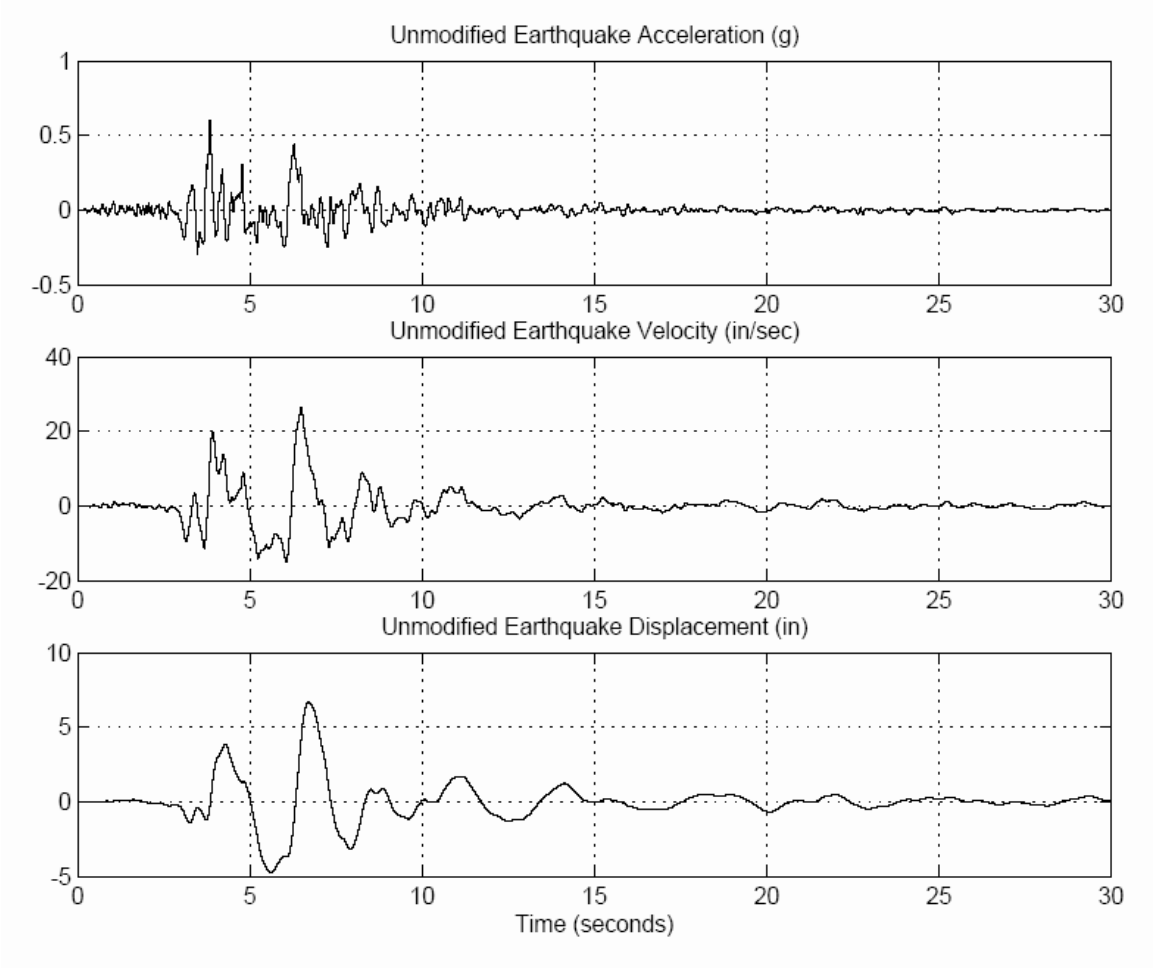


Fig. 2-12. Sylmar Earthquake Time History

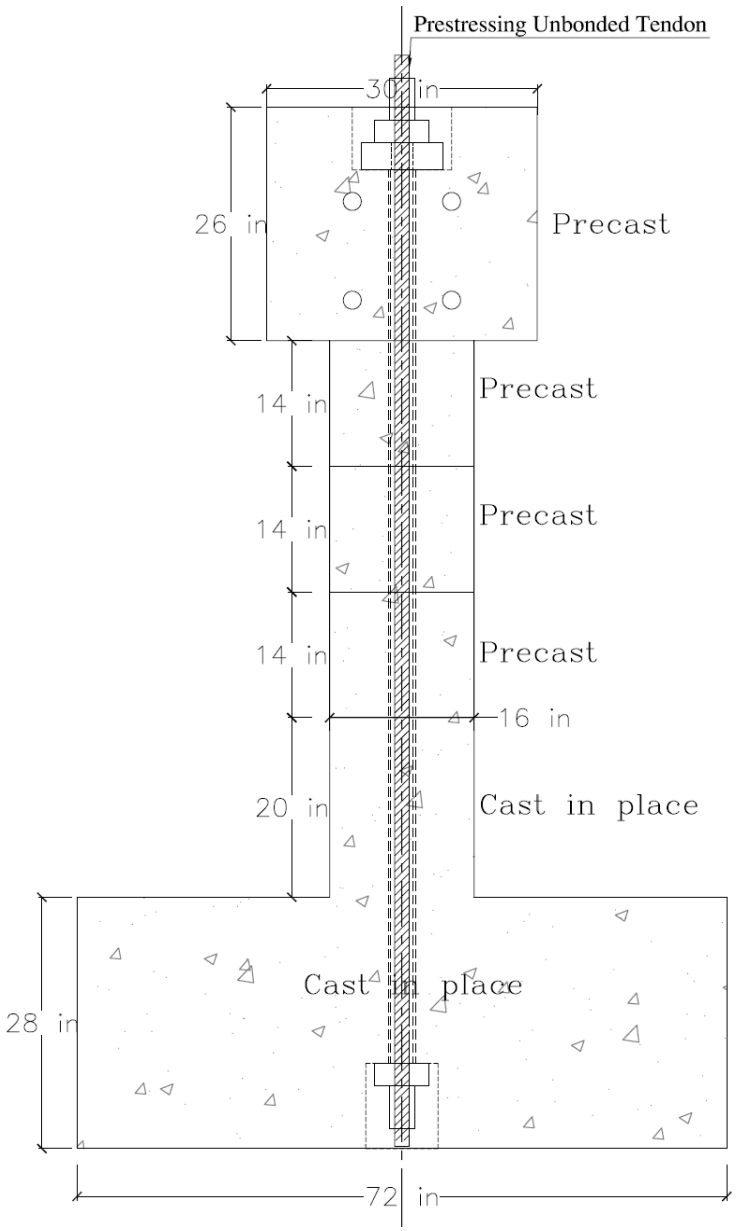


Fig. 2-13. SC-2 Column Detail

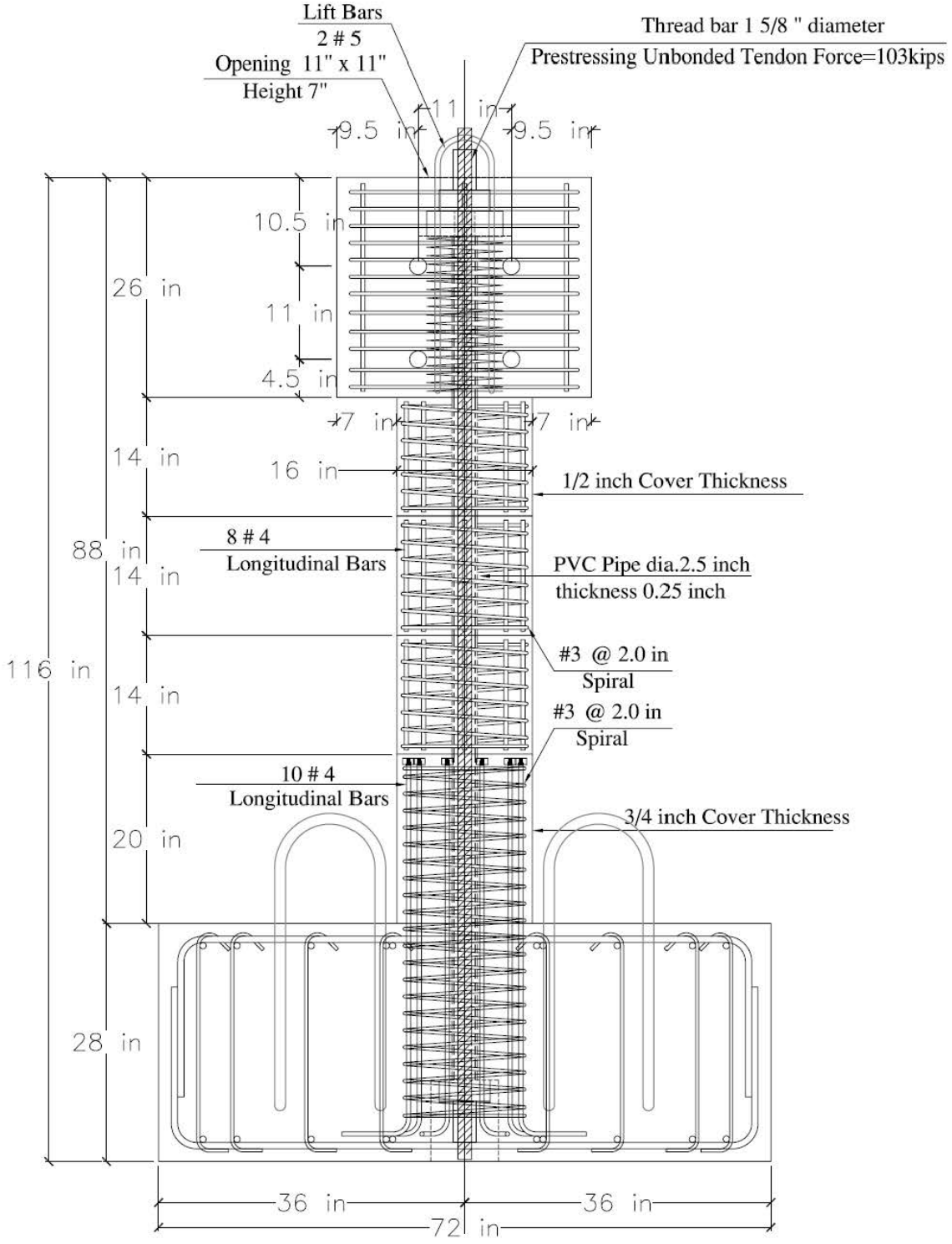


Fig. 2-14. SC-2 Column Reinforcement Detail

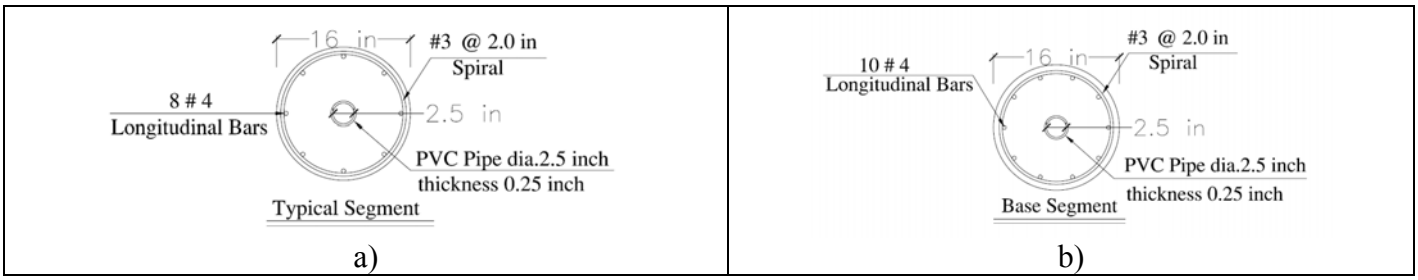


Fig. 2-15. Sections Detail for a) Typical Segment, b) Base Segment

Fig. 2-16. Base Segment Steel Cage

Fig. 2-17. a) Base Segment before Concrete Casting, b)Typical Segment Cage, c) Casting the Footing, d) Casting the Base Segment

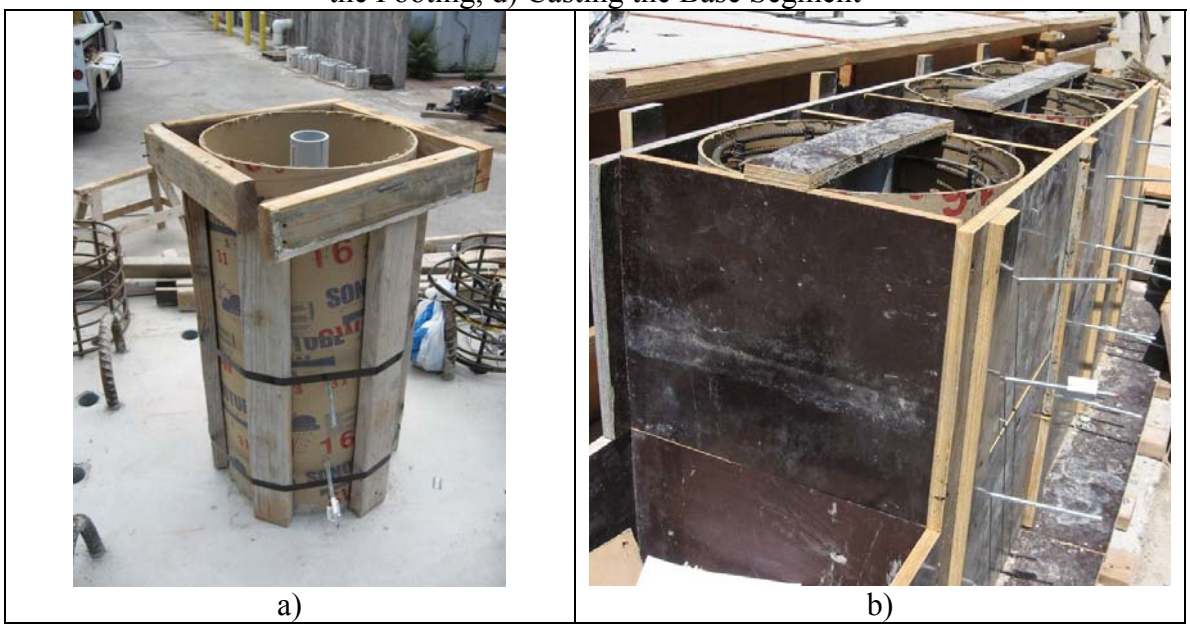


Fig. 2-18. a) Match Cast Construction of Second Segment, b) Match Cast Construction of Fourth Segment, c) Assembling the Column, d) Post-Tensioning

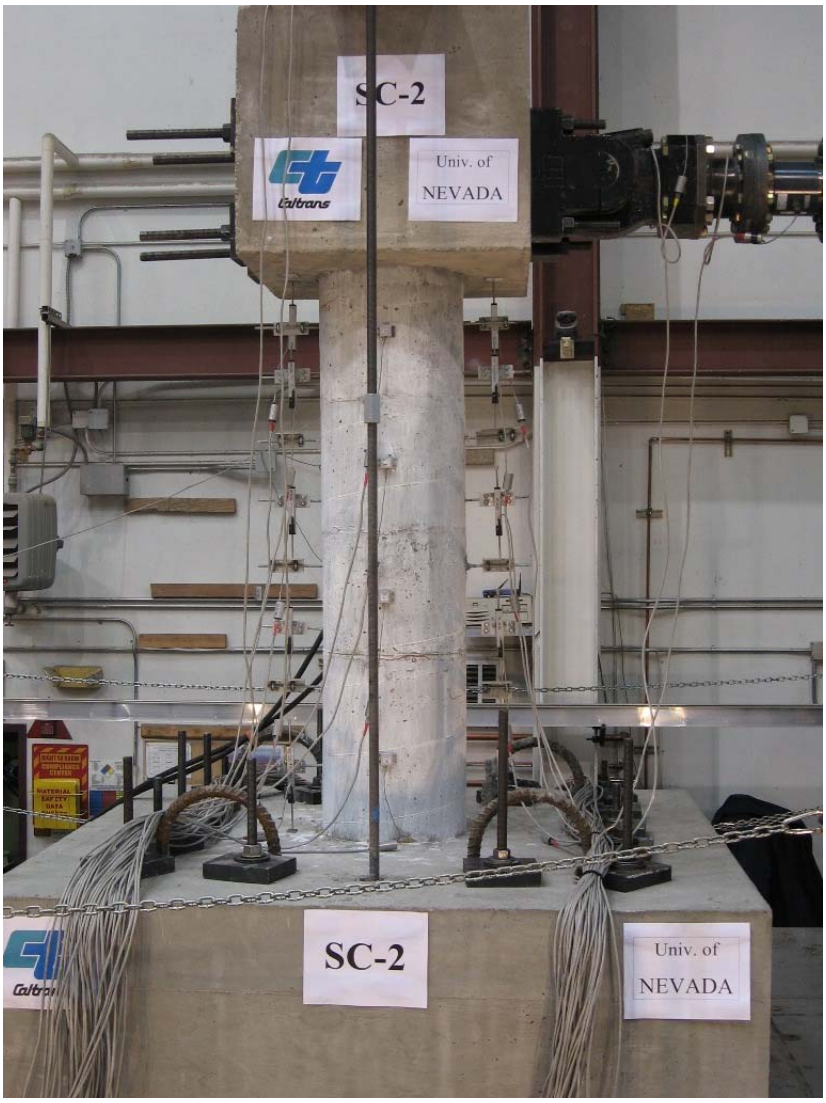


Fig. 2-19. Column SC-2 after Construction

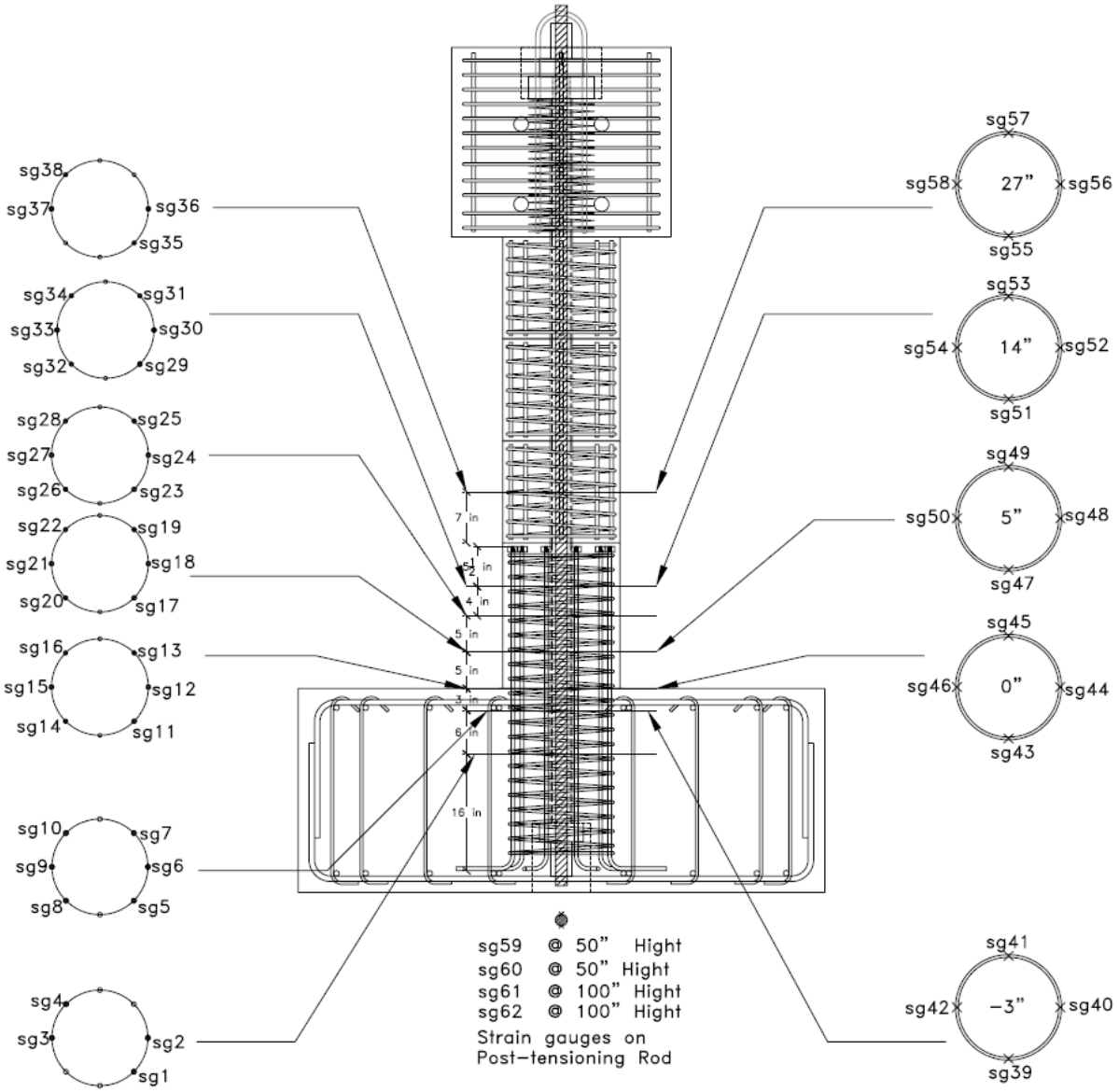


Fig. 2-20. SC-2 Strain Gauge Plan

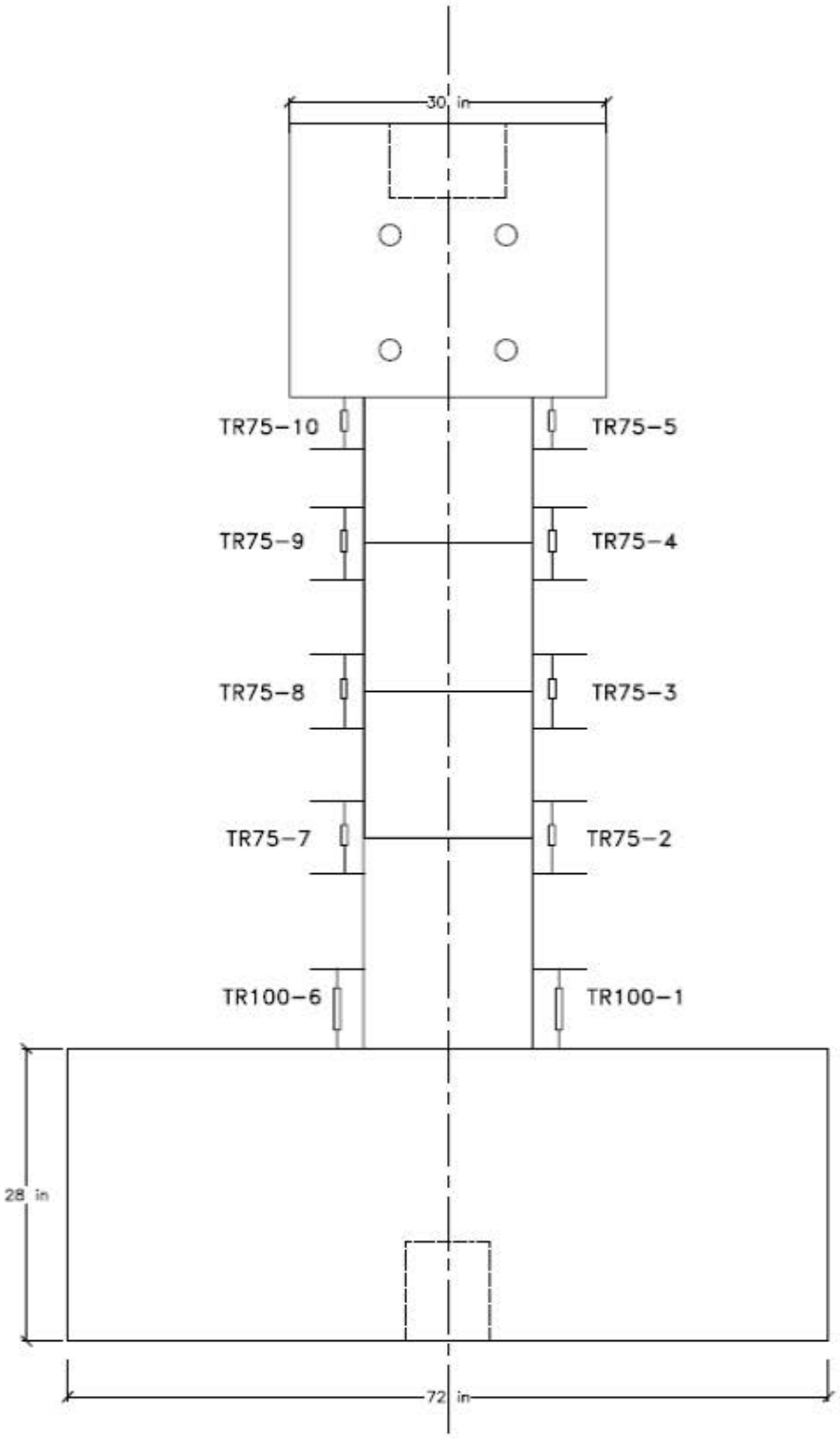


Fig. 2-21. SC-2 Novotechnik Plan

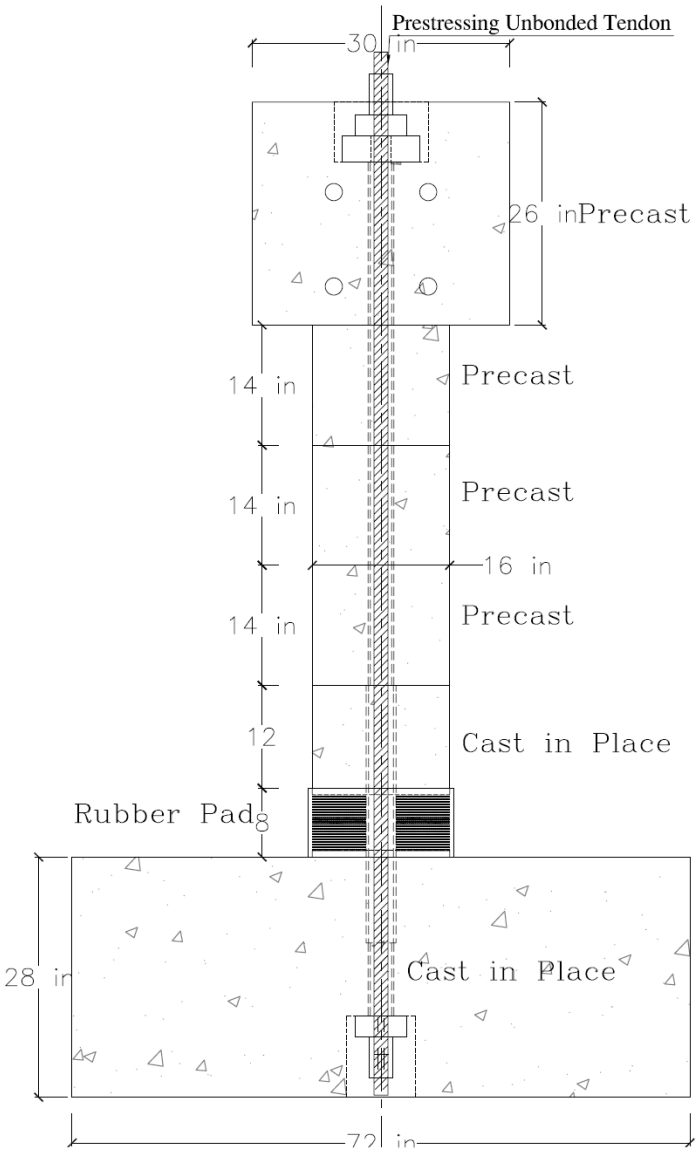


Fig. 2-22. SBR-1 Column Detail

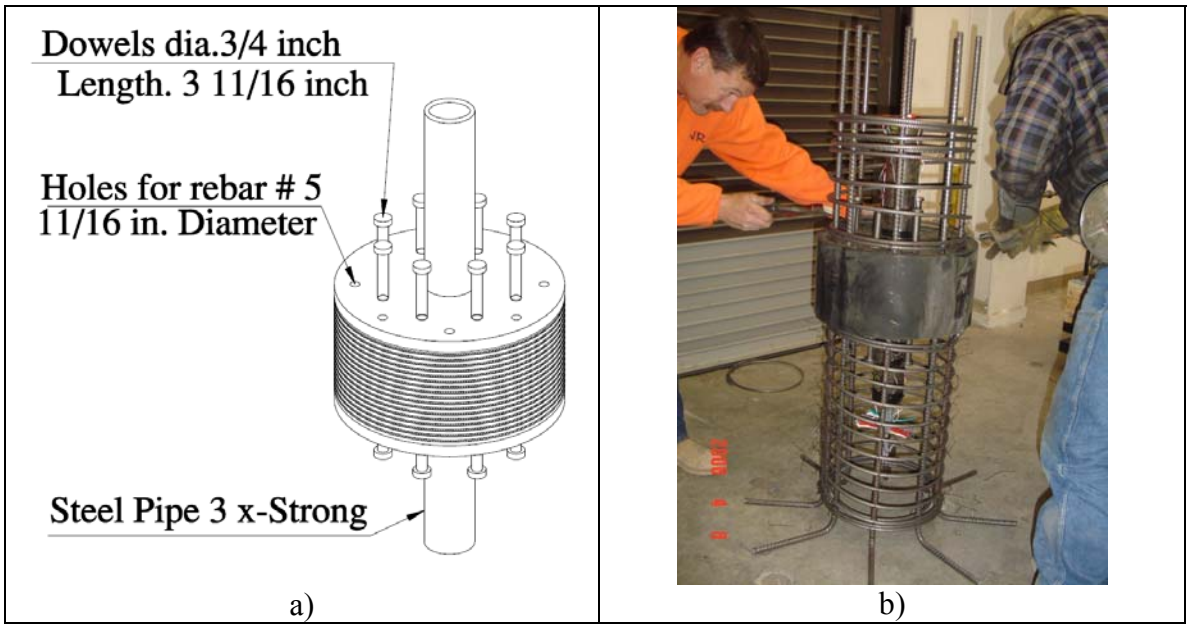


Fig. 2-23. a) Elastomeric Bearing Pad in SBR-1 b) Base Segment Configuration

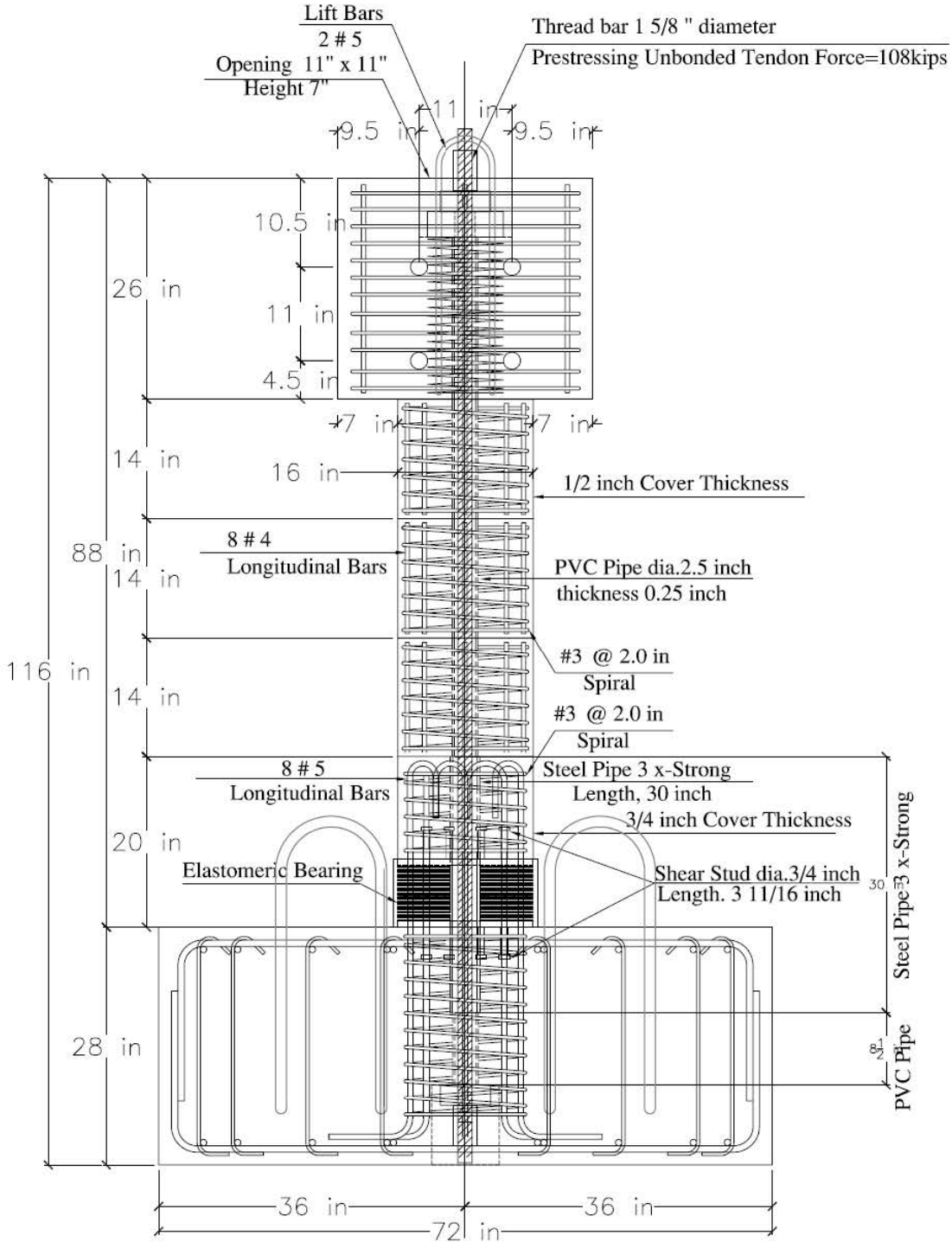
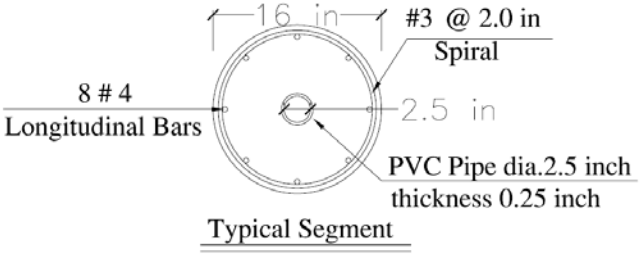
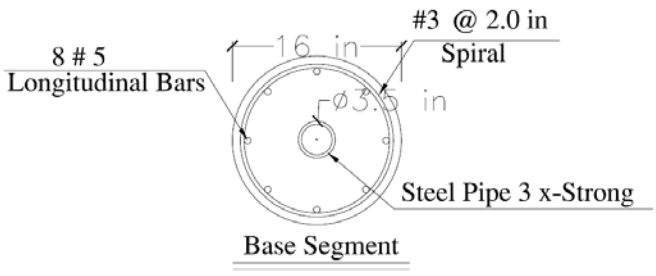


Fig. 2-24. SBR-1 Column Reinforcement Detail



a)



b)

Fig. 2-25. Sections Detail for a) Typical Segment, b) Base Segment

a)

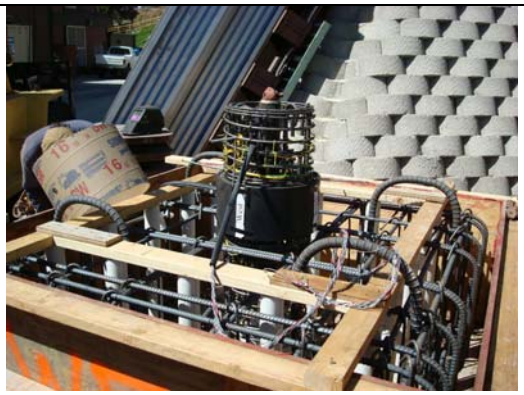
b)

Fig. 2-26. Base Segment, a) Steel Bars Placement, b) Bending the Longitudinal Bars End

a)

b)

Fig. 2-27. Typical Segments, a) Steel Cages, b) after Construction



a)

b)

Fig. 2-28. Footing, a) Steel Cage, b) After Concrete Casting

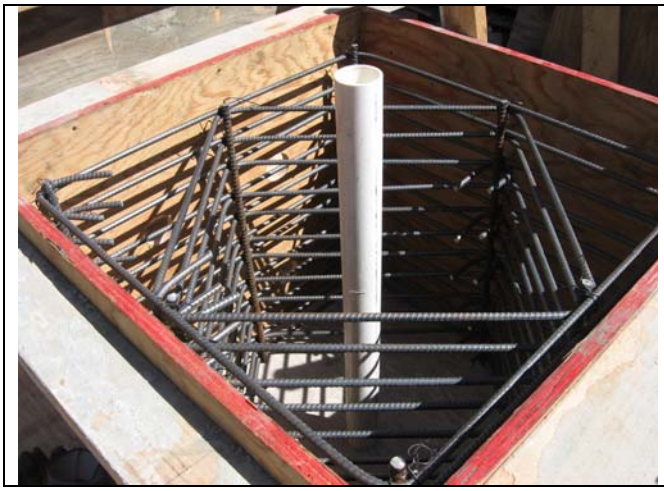


Fig. 2-29. Head block, a) Steel Cage, b) after Construction

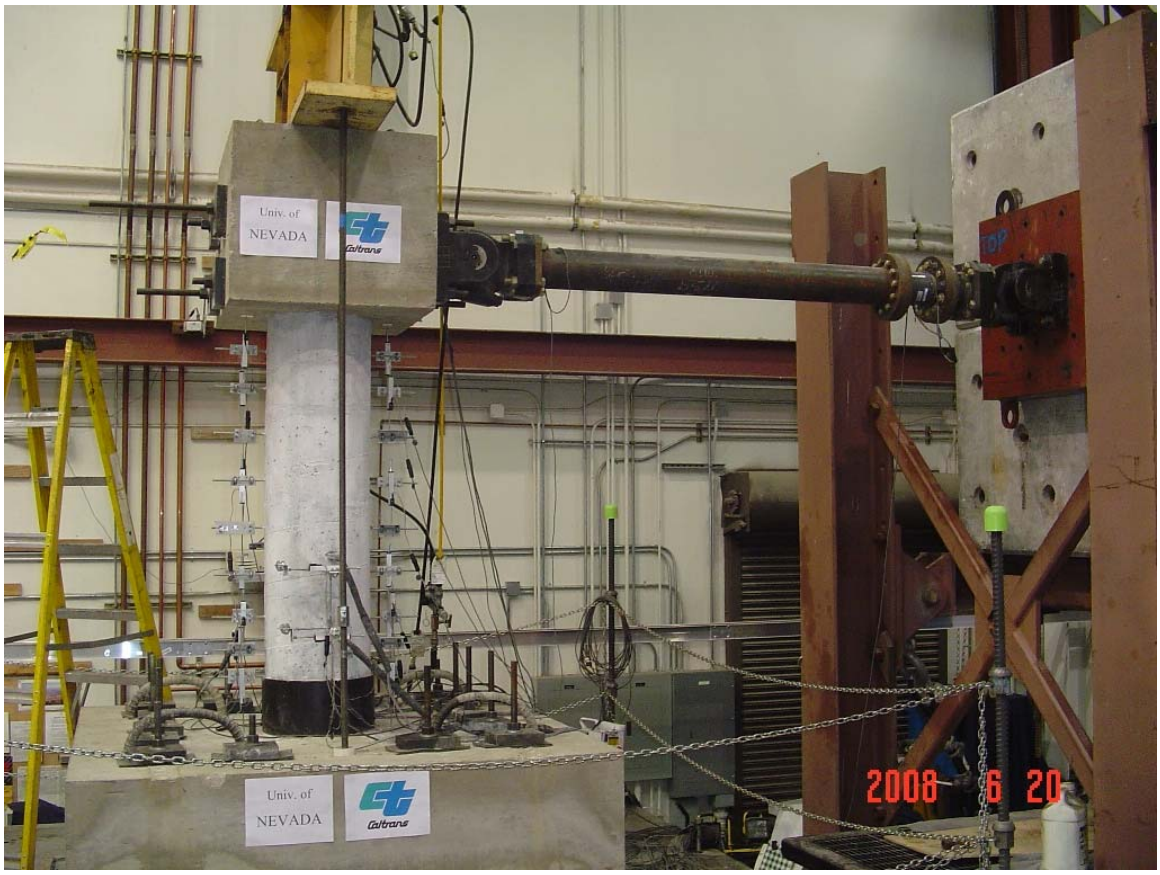


Fig. 2-30. SBR-1 after Construction

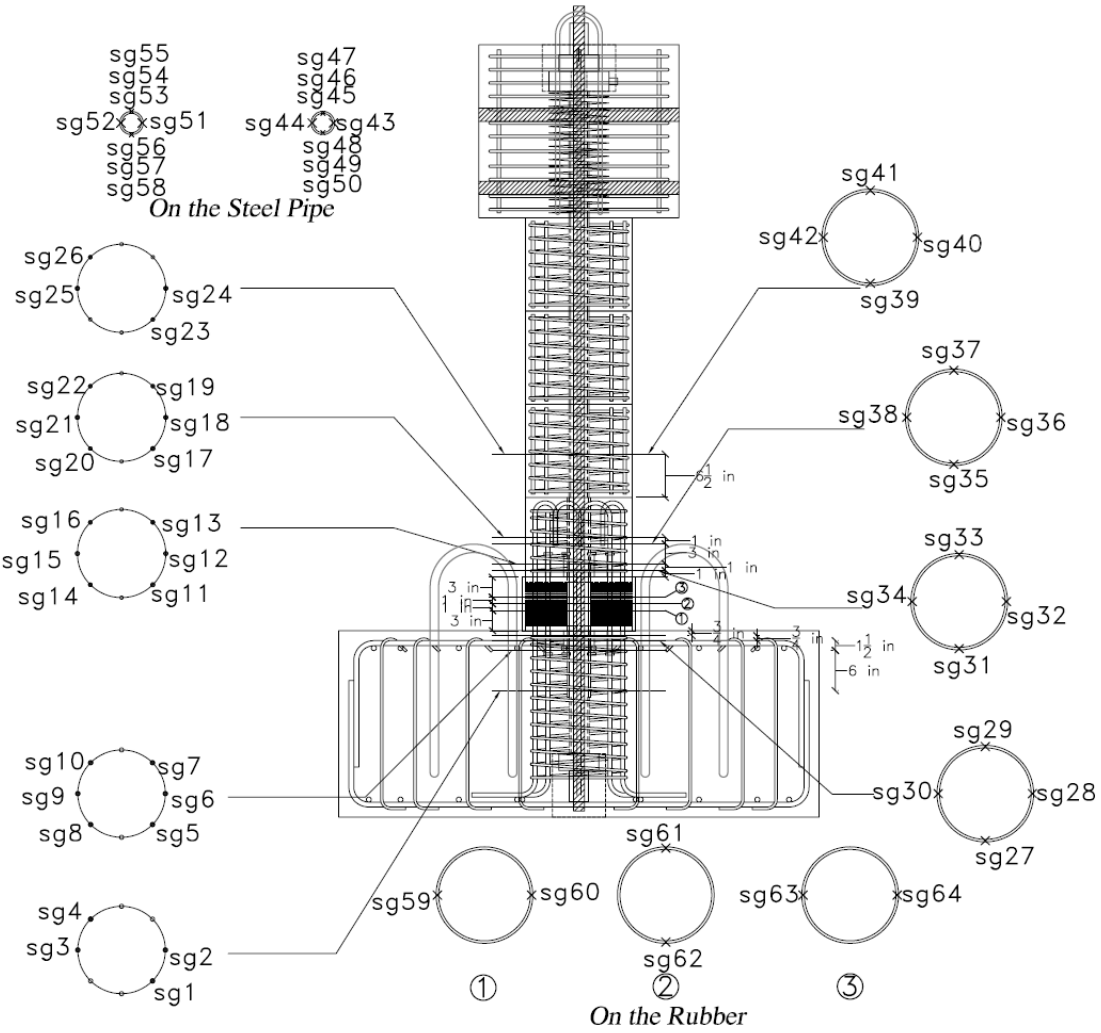


Fig. 2-31. SBR-1 Strain Gauge Plan

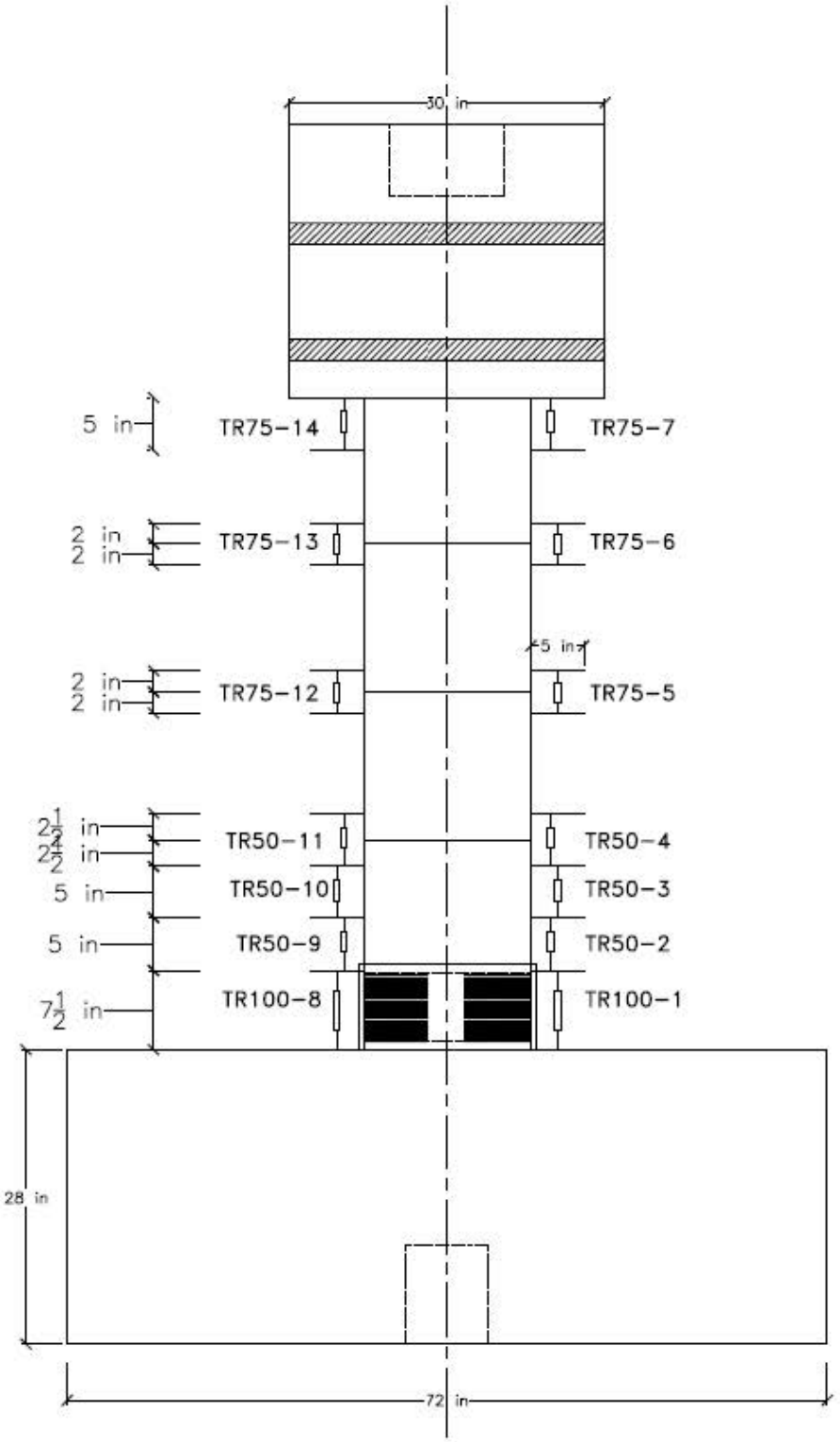


Fig. 2-32. SBR-1 Novotechnik Plan

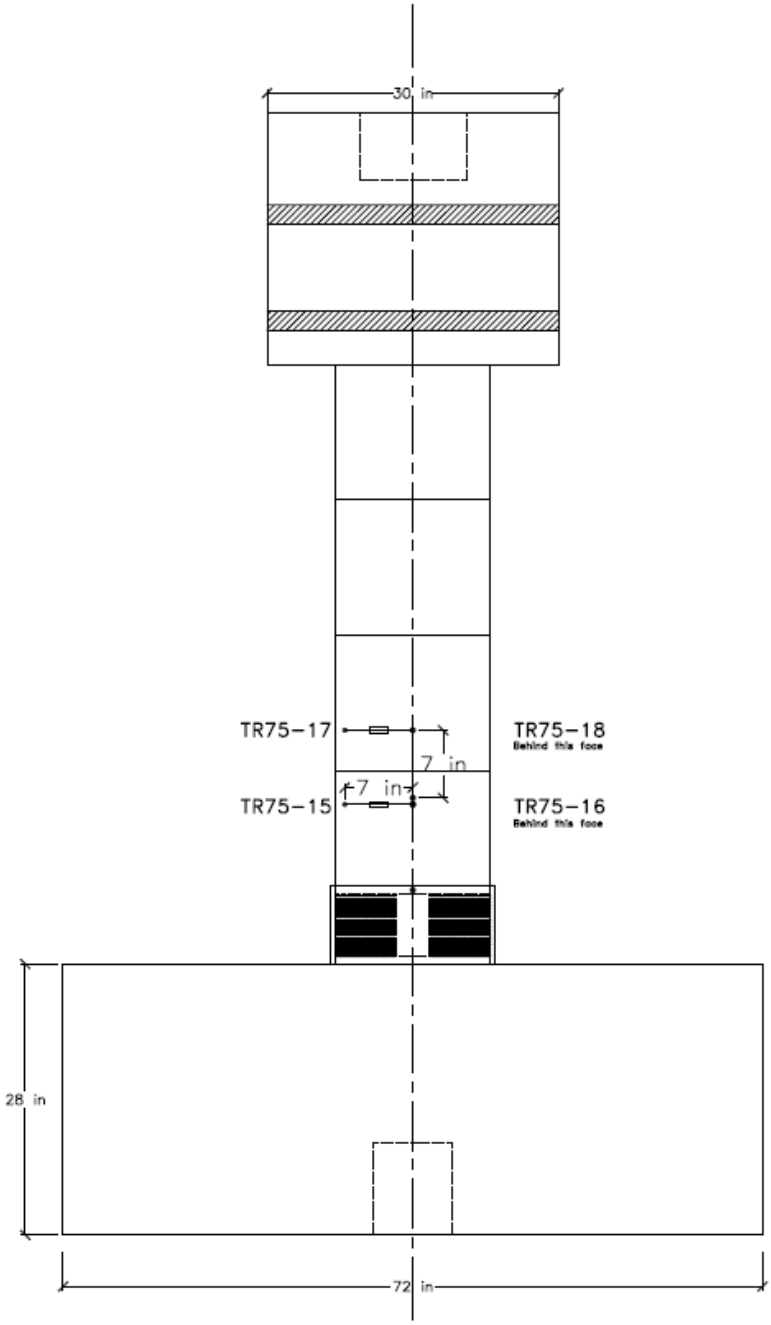


Fig. 2-33. SBR-1 Horizontal Novotechnik Plan

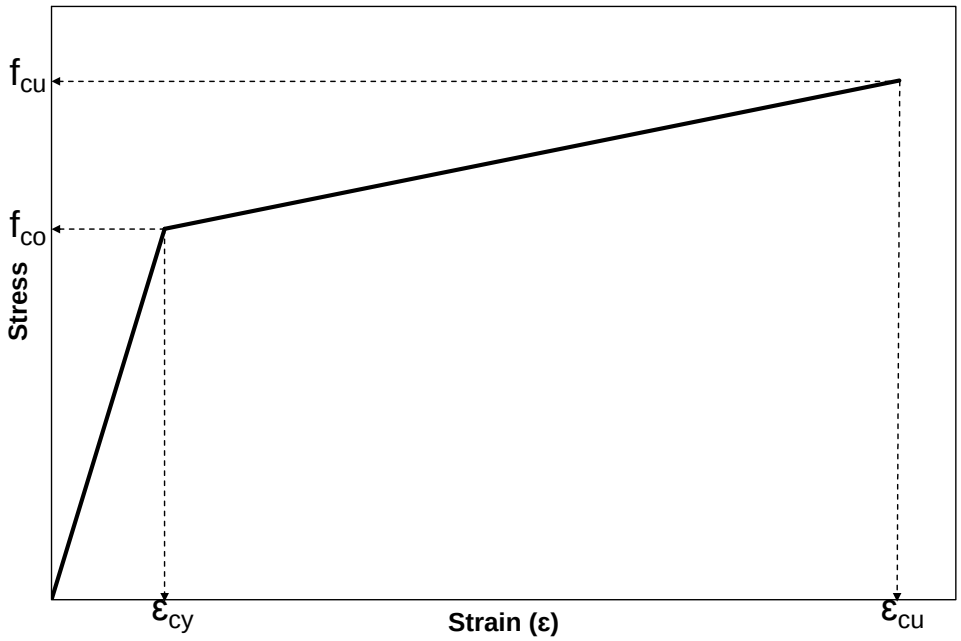


Fig. 2-34. Stress-Strain Bilinear Model for Concrete Confined with FRP

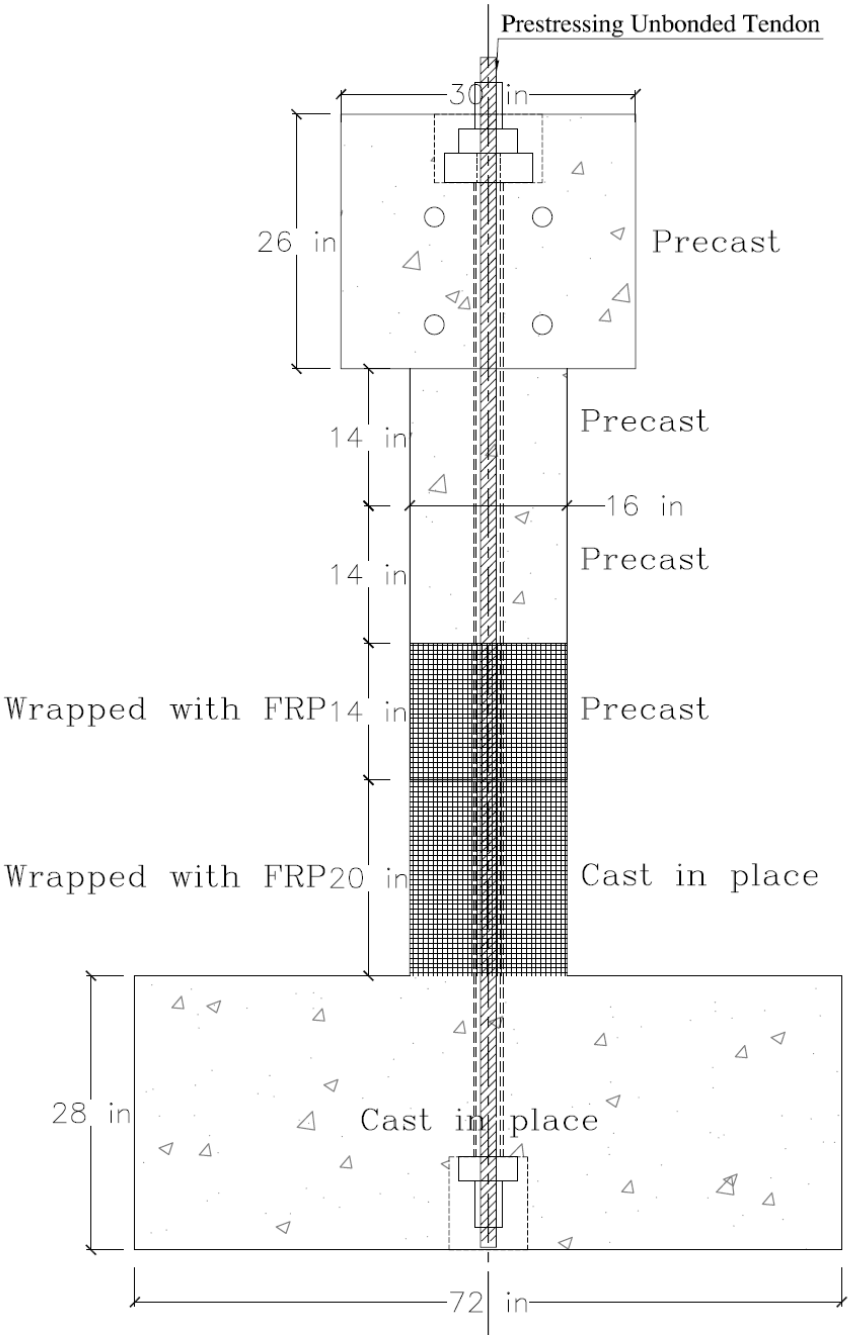


Fig. 2-35. SF-2 Column Detail

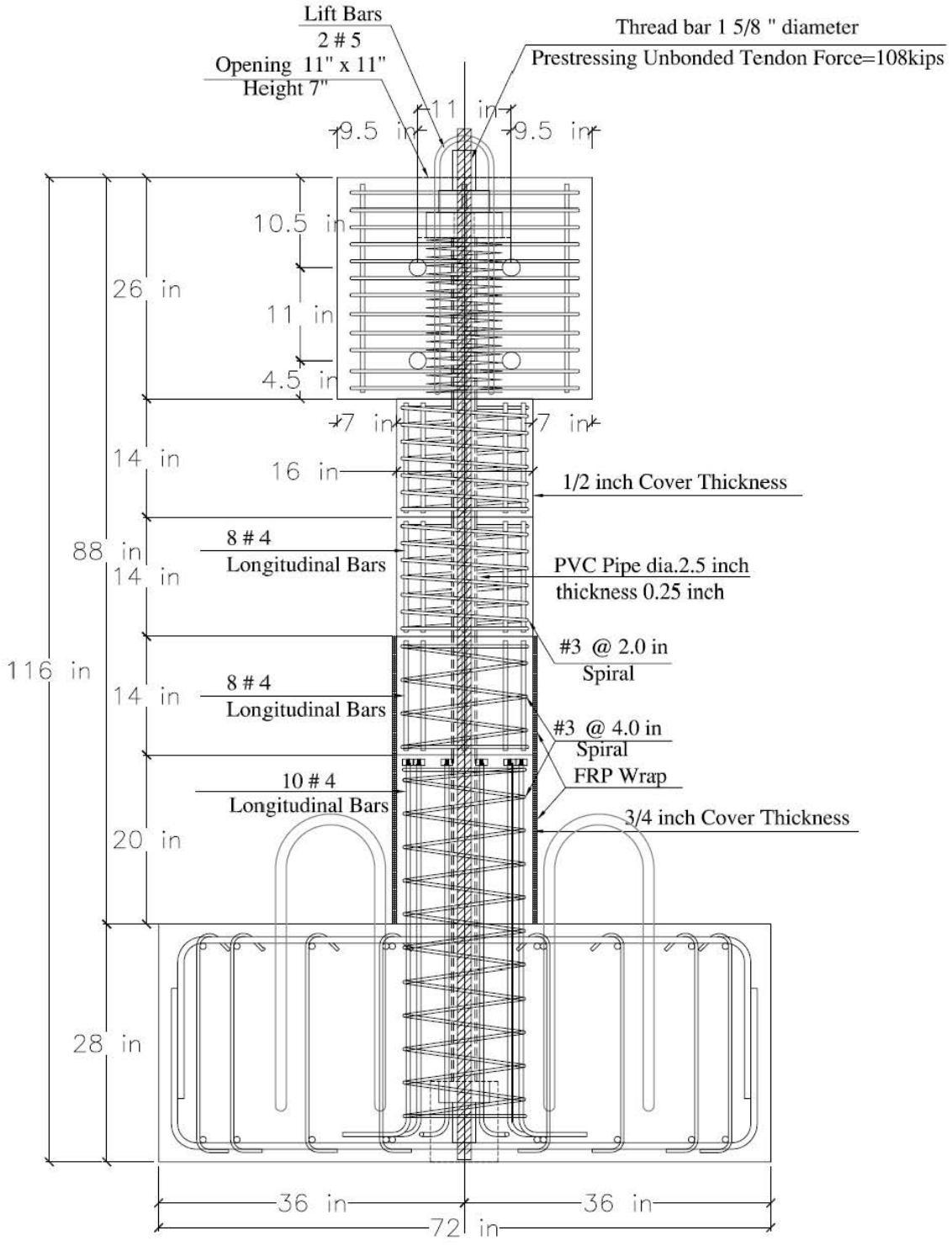


Fig. 2-36. SF-2 Column Reinforcement Detail

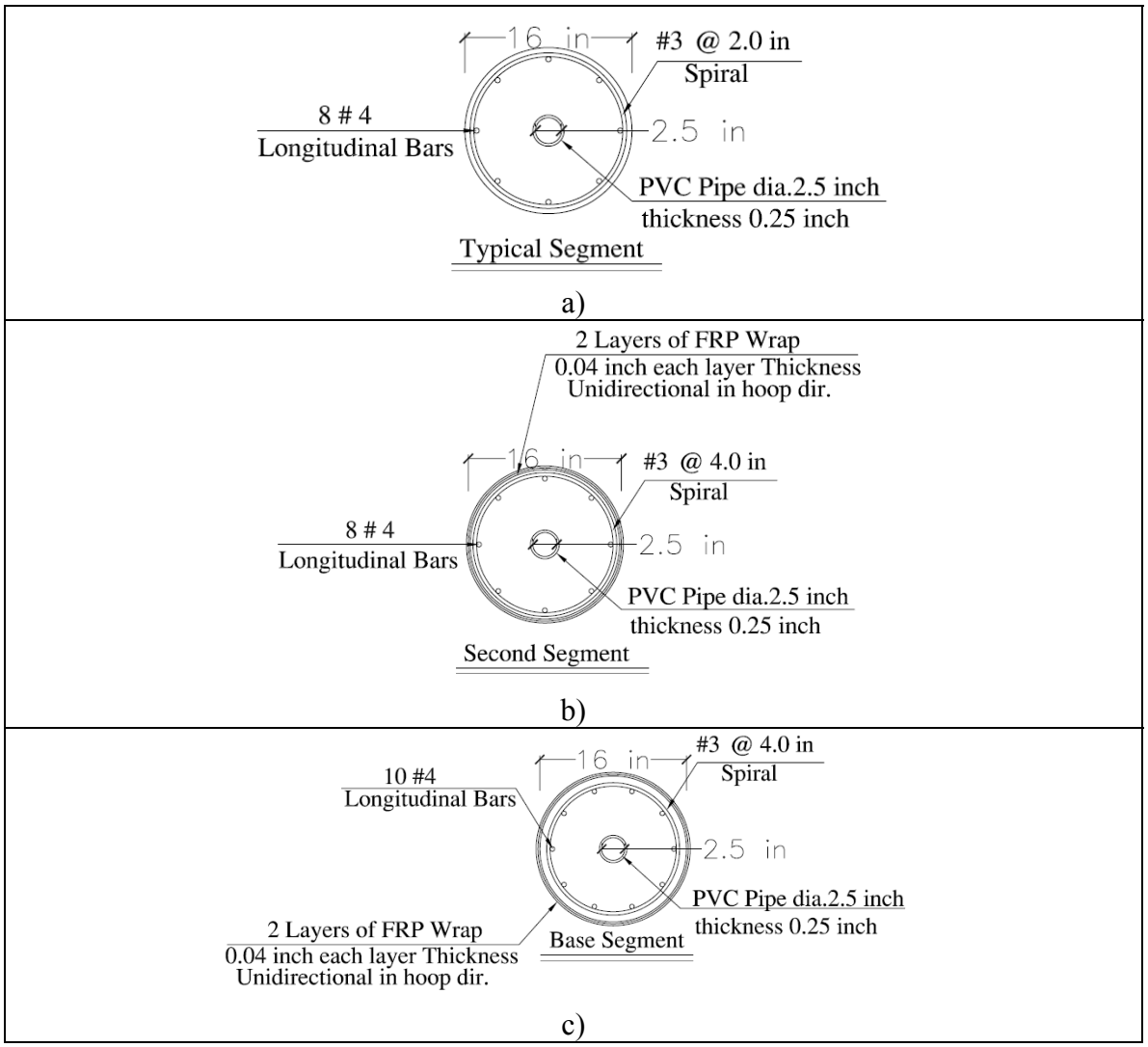


Fig. 2-37. Sections Detail for a) Typical Segment, b) Second Segment, c) Base Segment

Fig. 2-38. SF-2 Footing and Base Segment, a) Before Casting, b) After Casting

a) b)

Fig. 2-39. a) Typical Segment Column Cages, b) Constructing the Second Segment with Match Cast Method

a) b)

Fig. 2-40. a) Preparing the Surface, b) FRP Wrapping

Fig. 2-41. SF-2 after Construction and Assembly

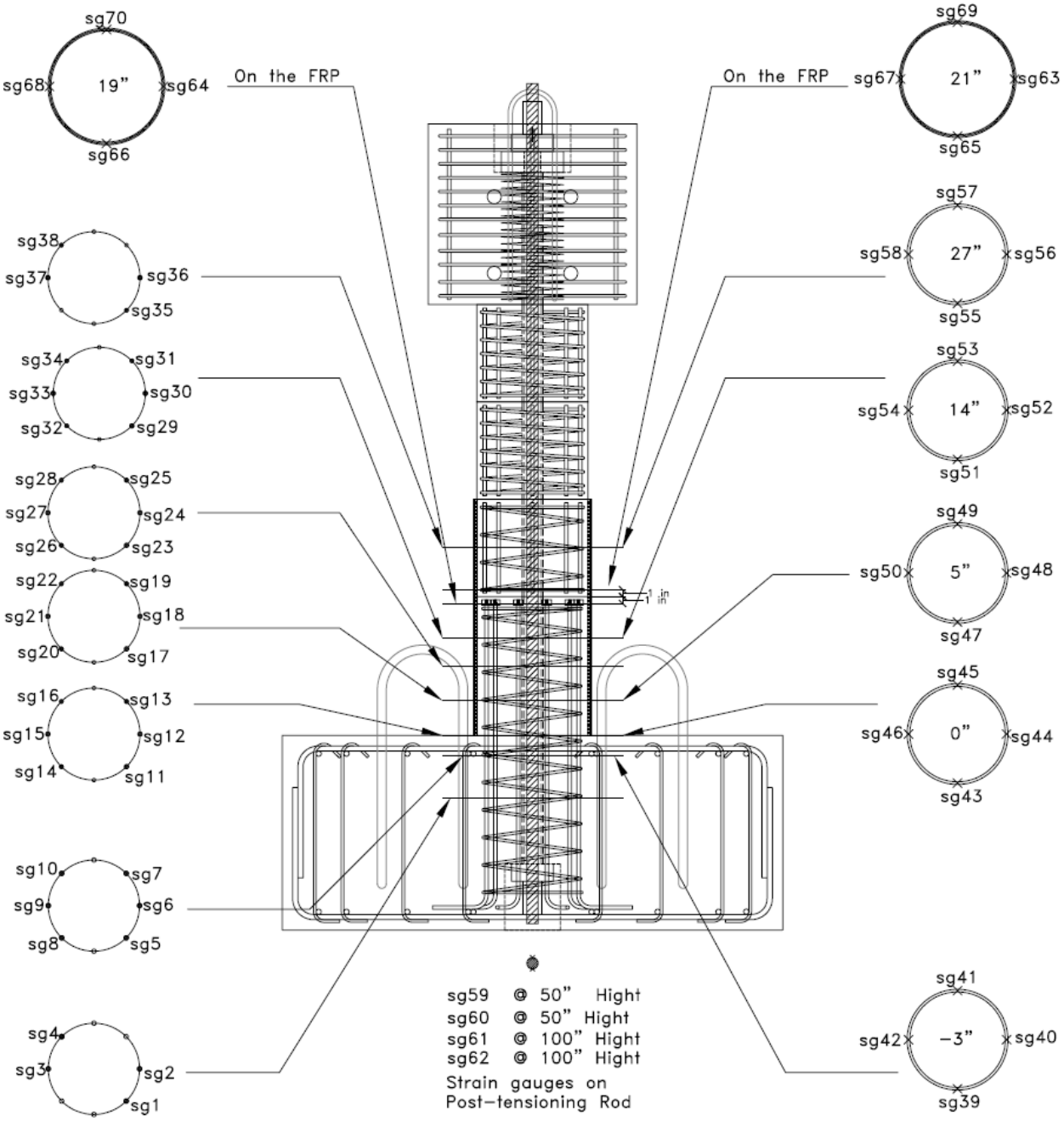


Fig. 2-42. SF-2 Strain Gauge Plan

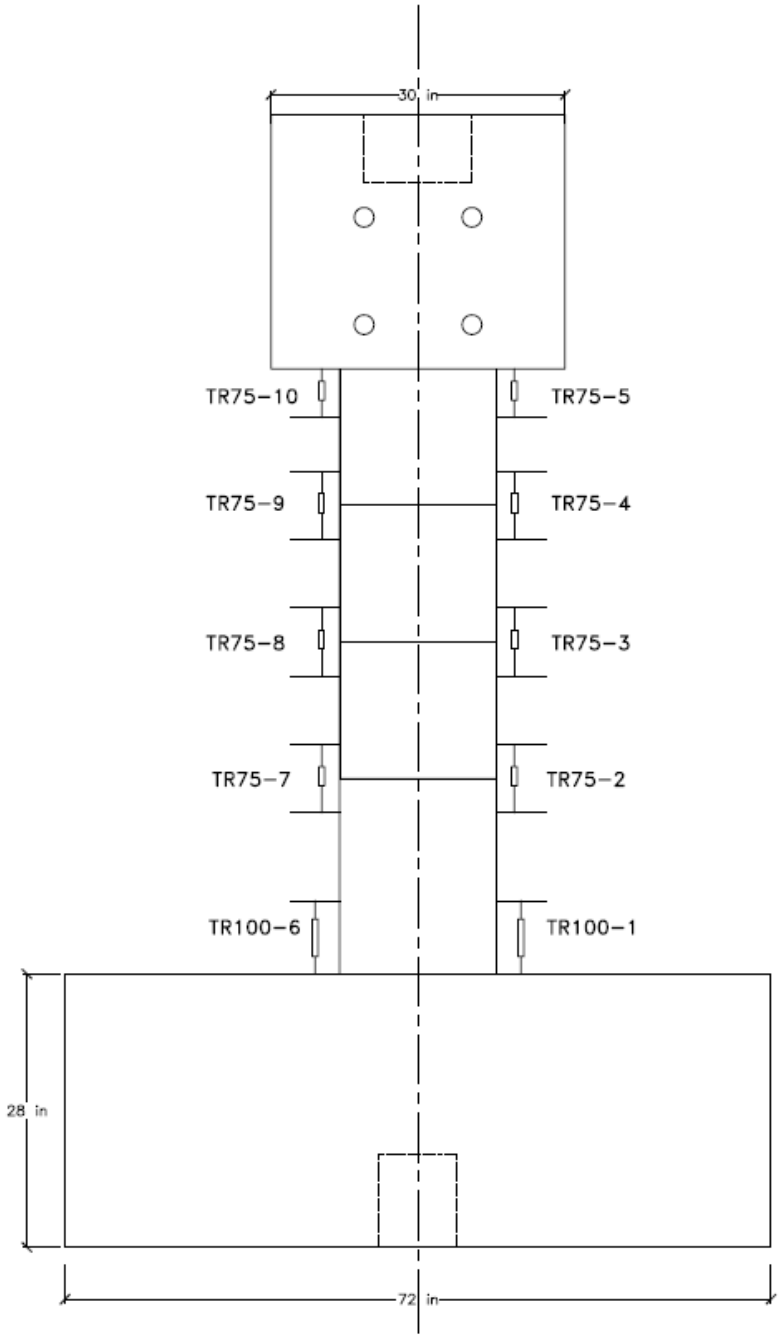


Fig. 2-43. SF-2 Novotechnik Plan

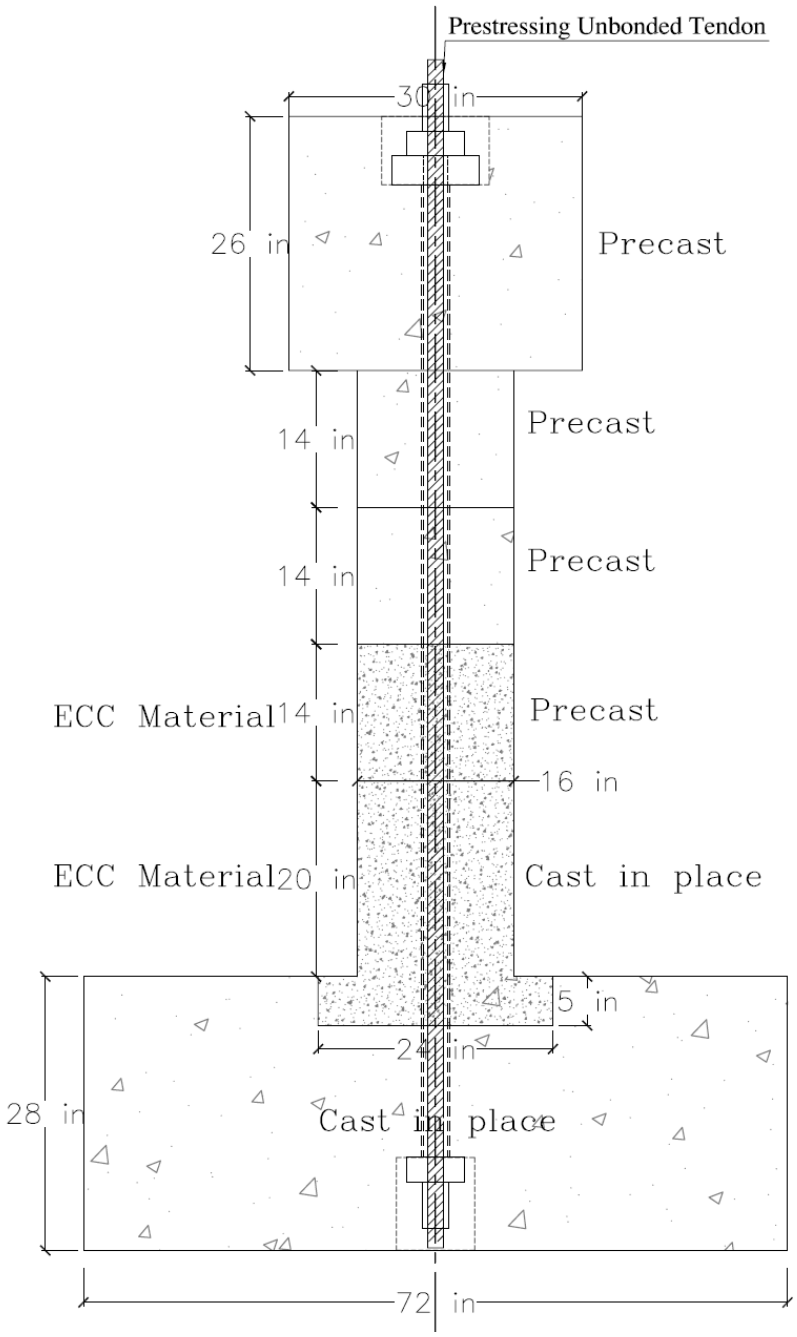


Fig. 2-44. SE-2 Column Detail

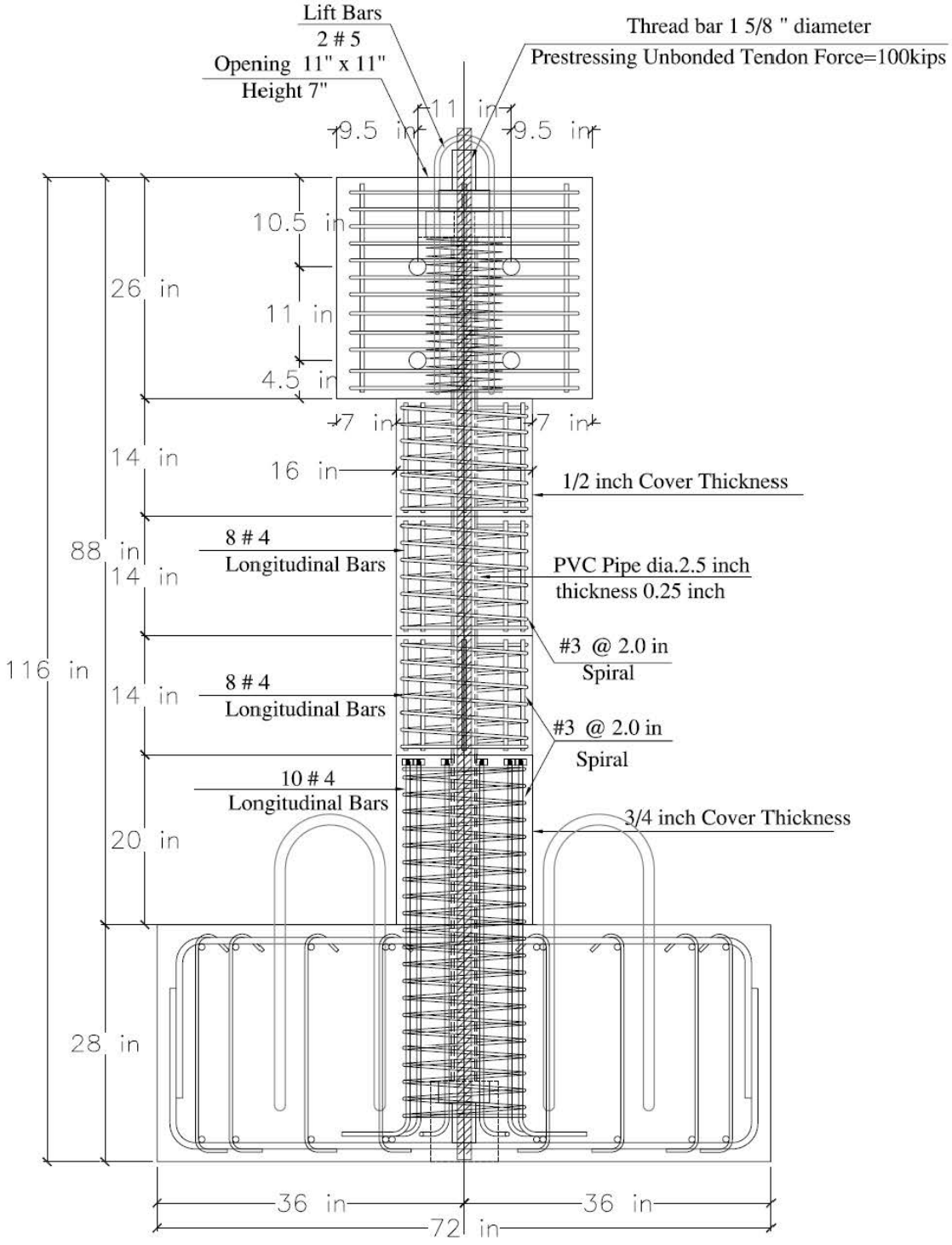


Fig. 2-45. SE-2 Column Reinforcement Detail

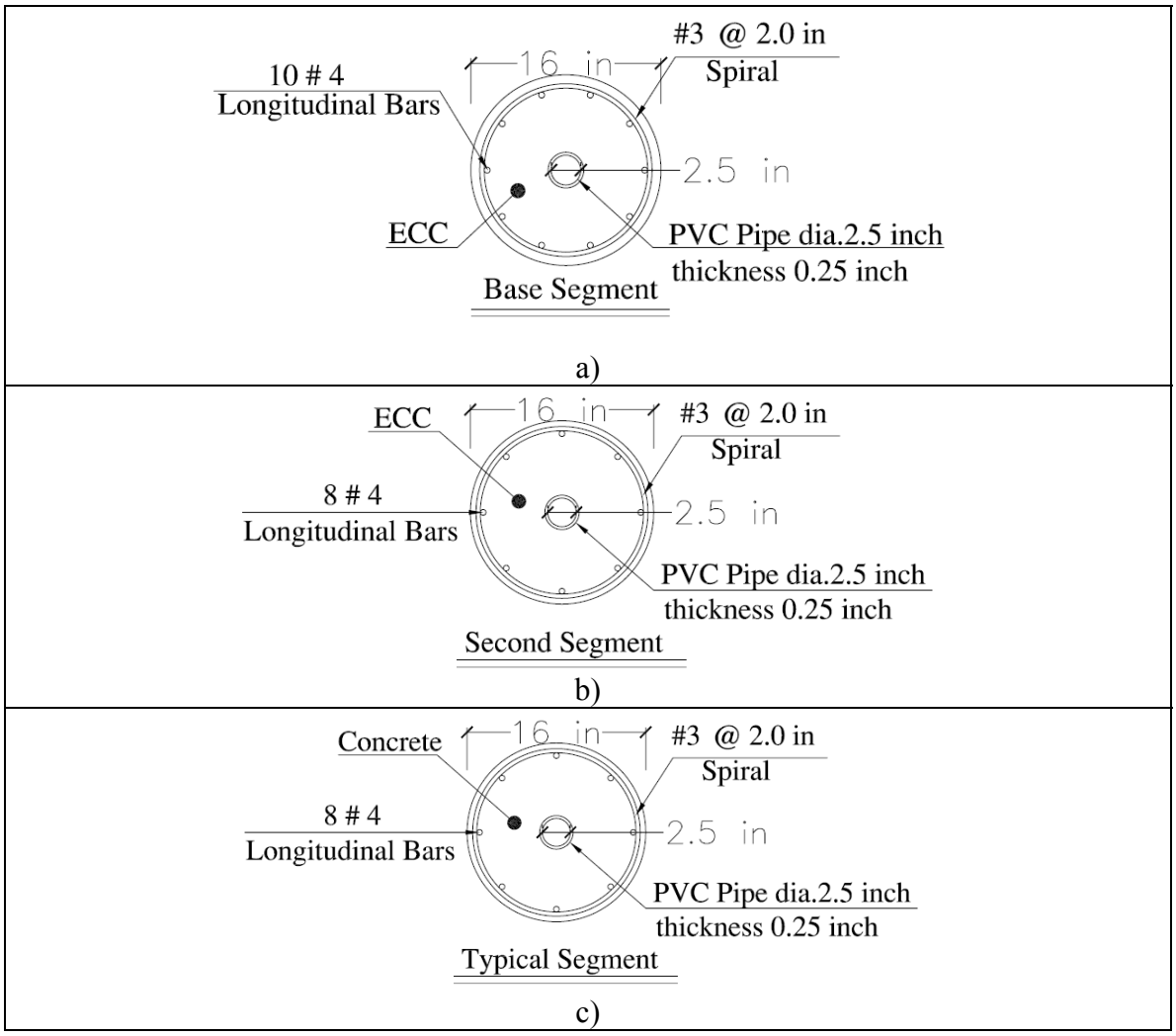


Fig. 2-46. Sections Detail for a) Base Segment, b) Second Segment, c) Typical Segment

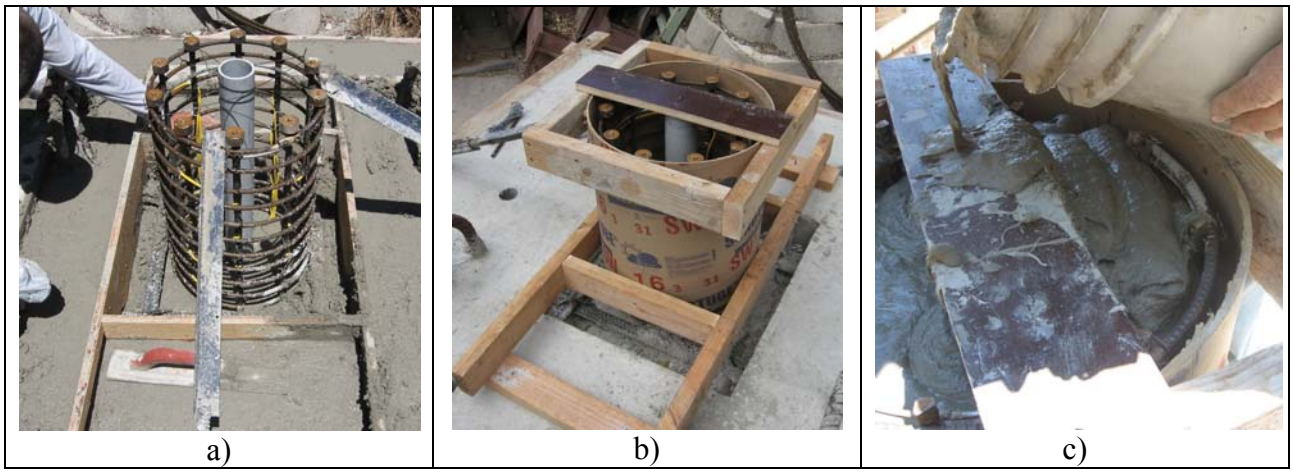


Fig. 2-47. SE-2 a) Casting of Concrete in the Footing, b) Base Segment, c) Casting of ECC

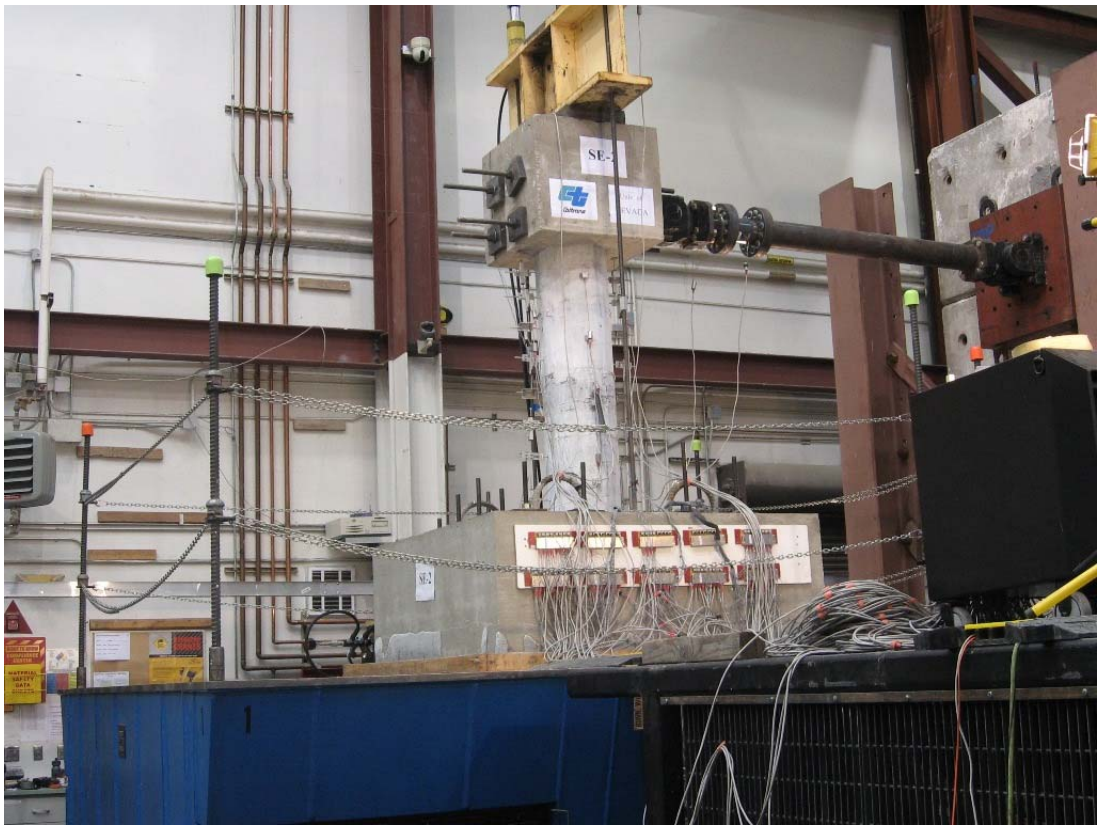


Fig. 2-48. SE-2 after Construction and Assembly

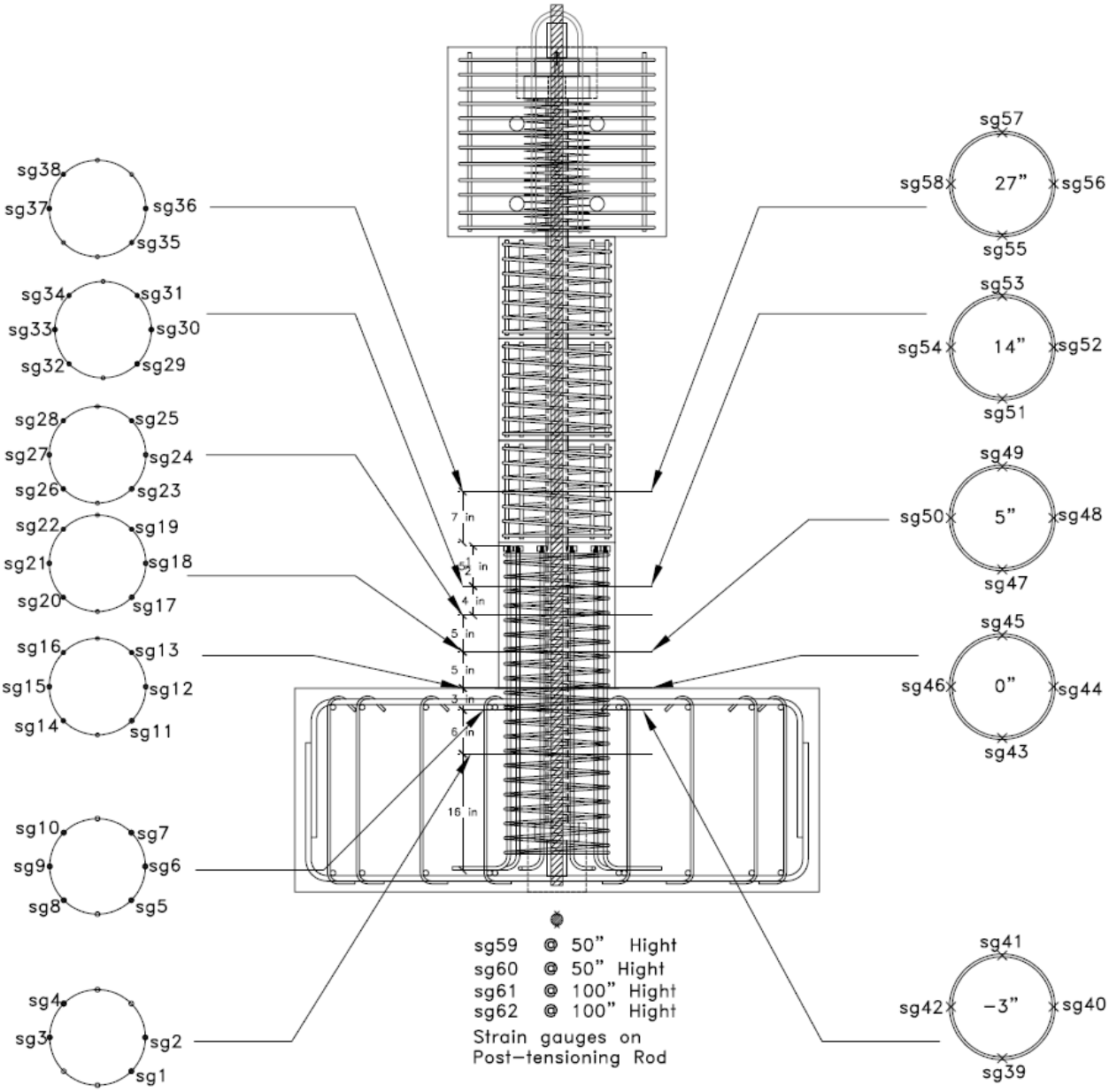


Fig. 2-49. SE-2 Strain Gauge Plan

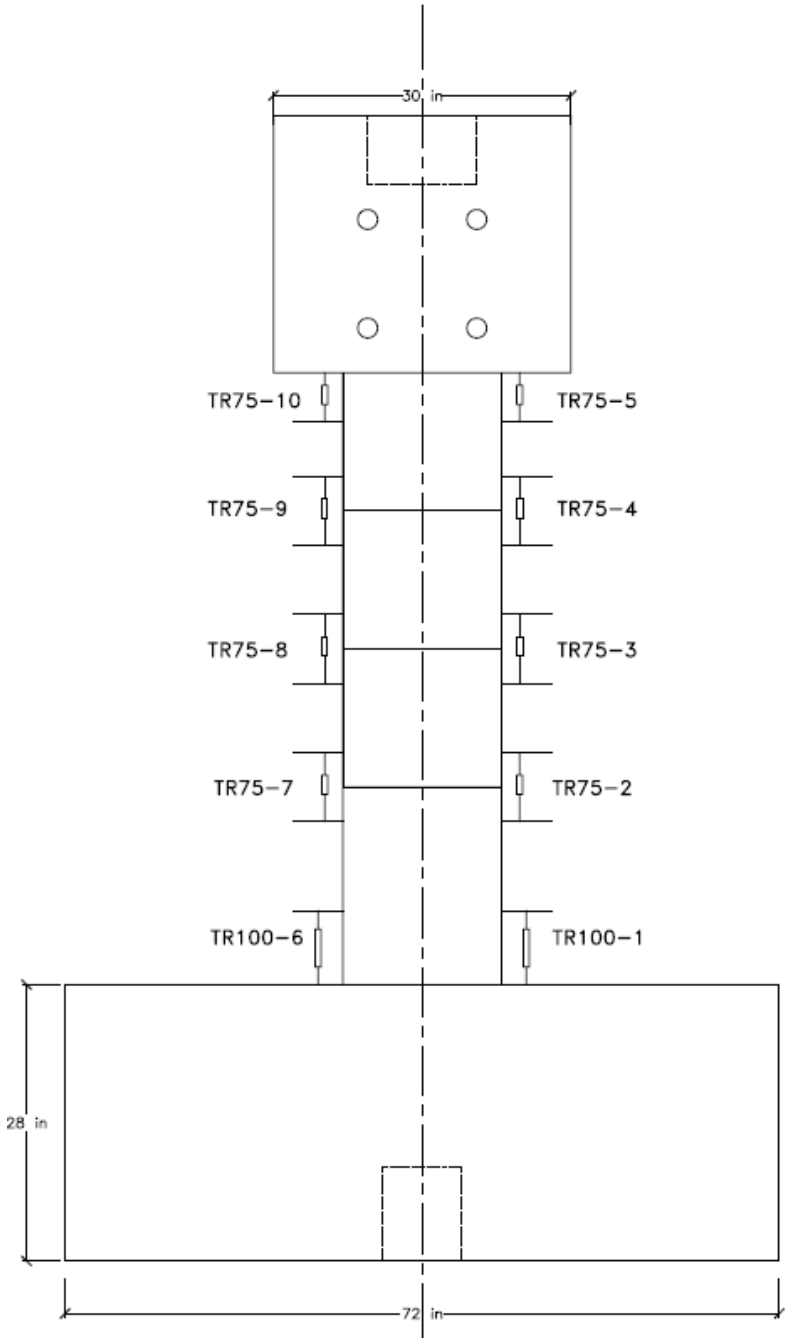


Fig. 2-50. SE-2 Novotechnik Plan

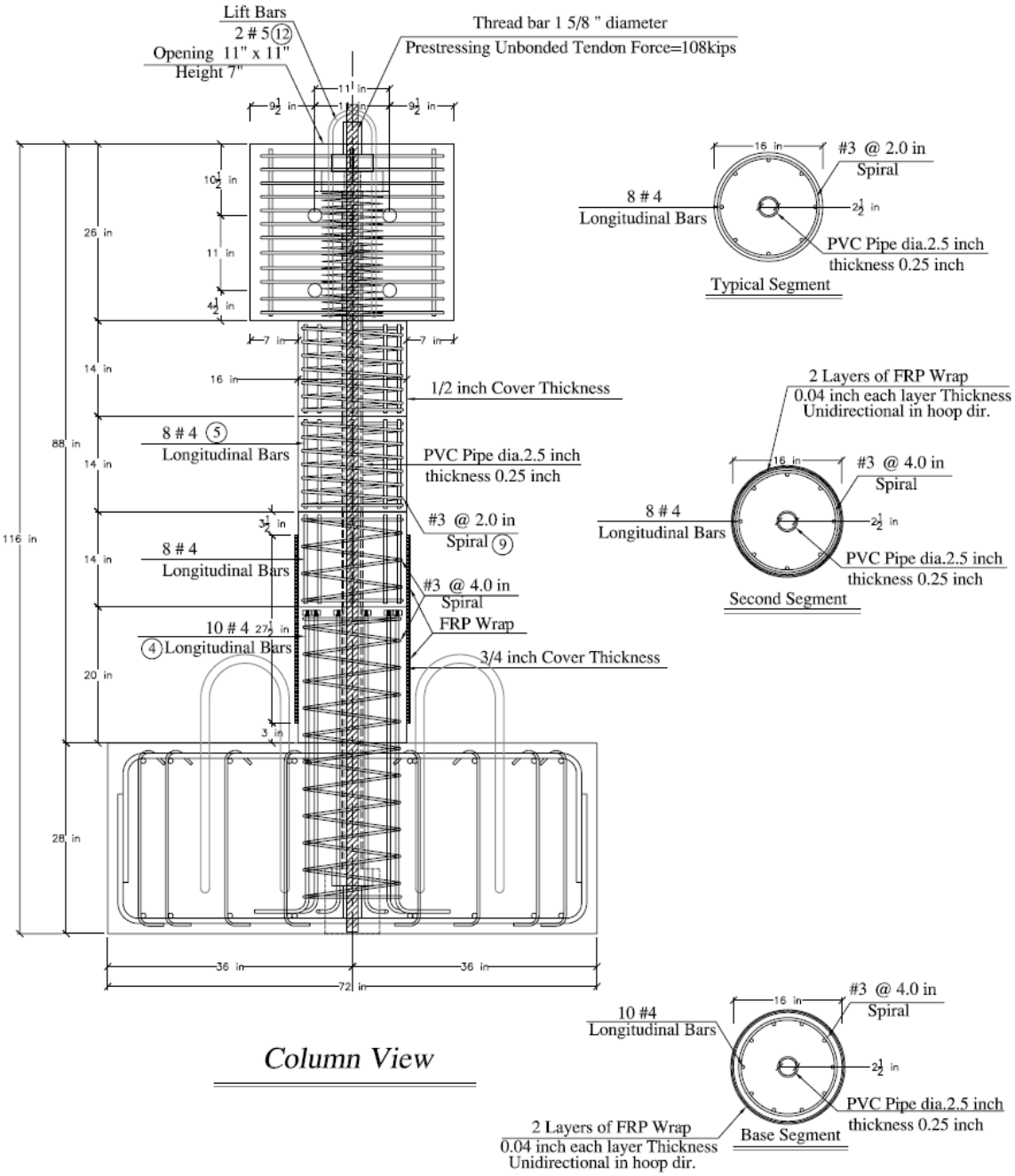


Fig. 2-51. SC-2R Column Reinforcement Detail

Fig. 2-52. SC-2R Repair Process, Removing Loose Concrete

Fig. 2-53. Patching SC-2R with High Strength Grout

Fig. 2-54. FRP Wrapping for Column SC-2R

Fig. 2-55. Column SC-2R before Test

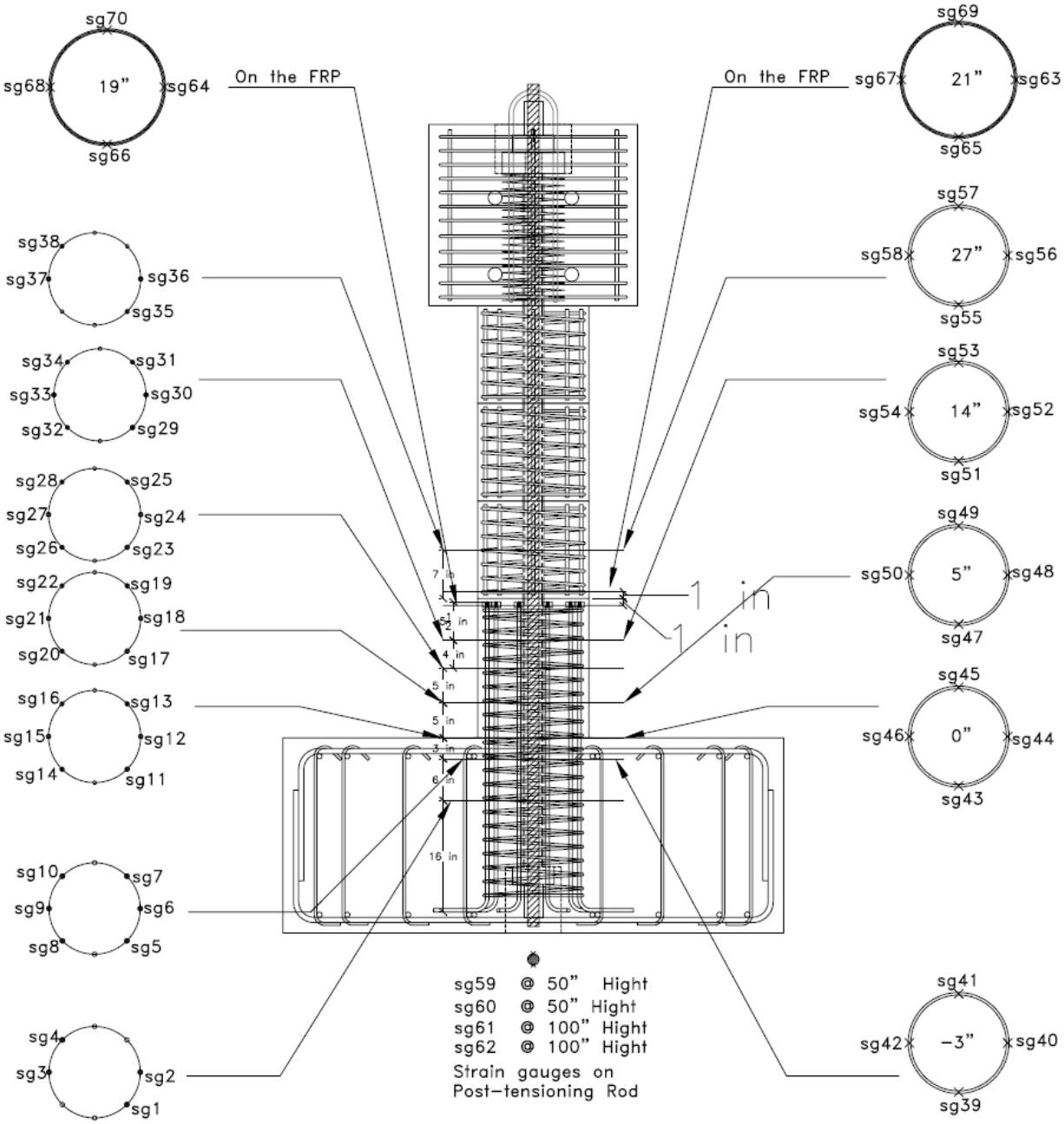


Fig. 2-56. SC-2R Strain Gauge Plan

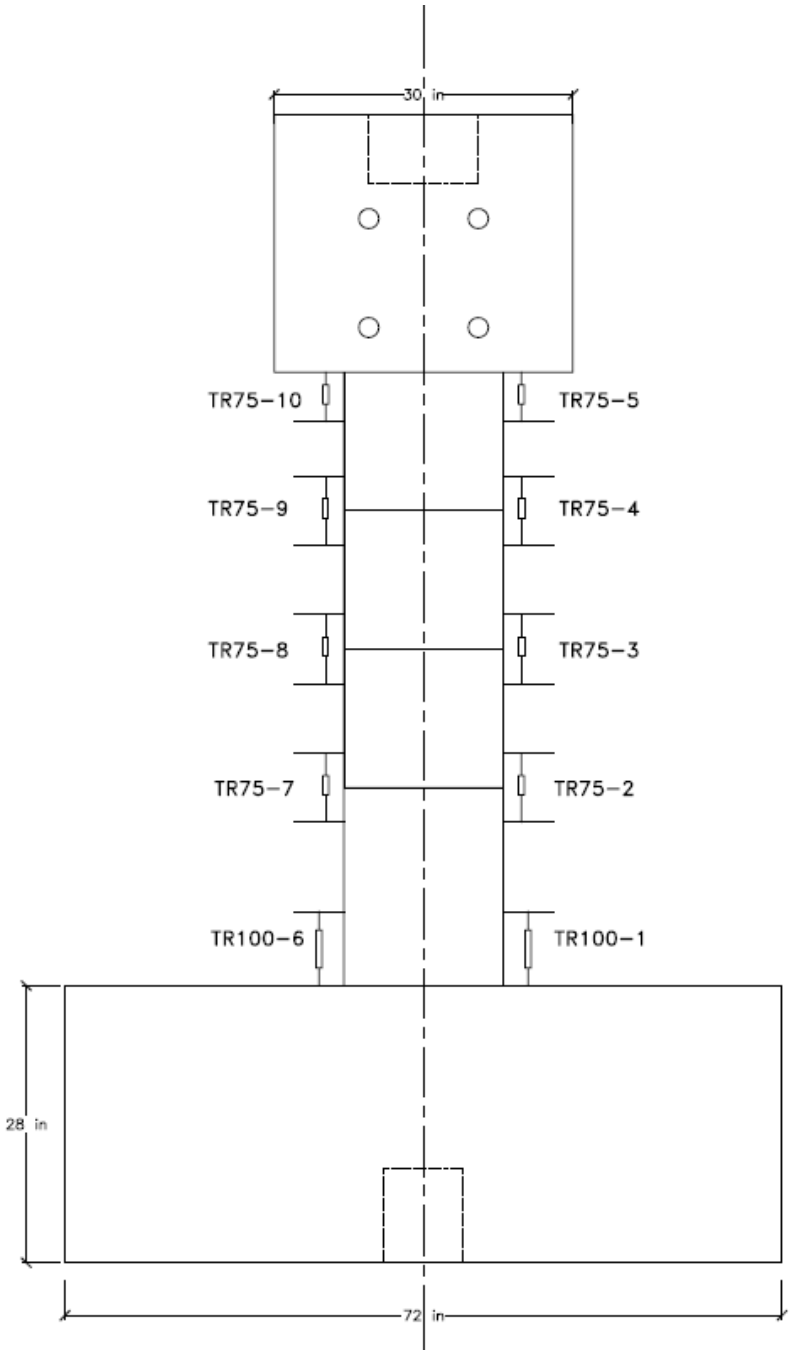


Fig. 2-57. SC-2R Novotechnik Plan

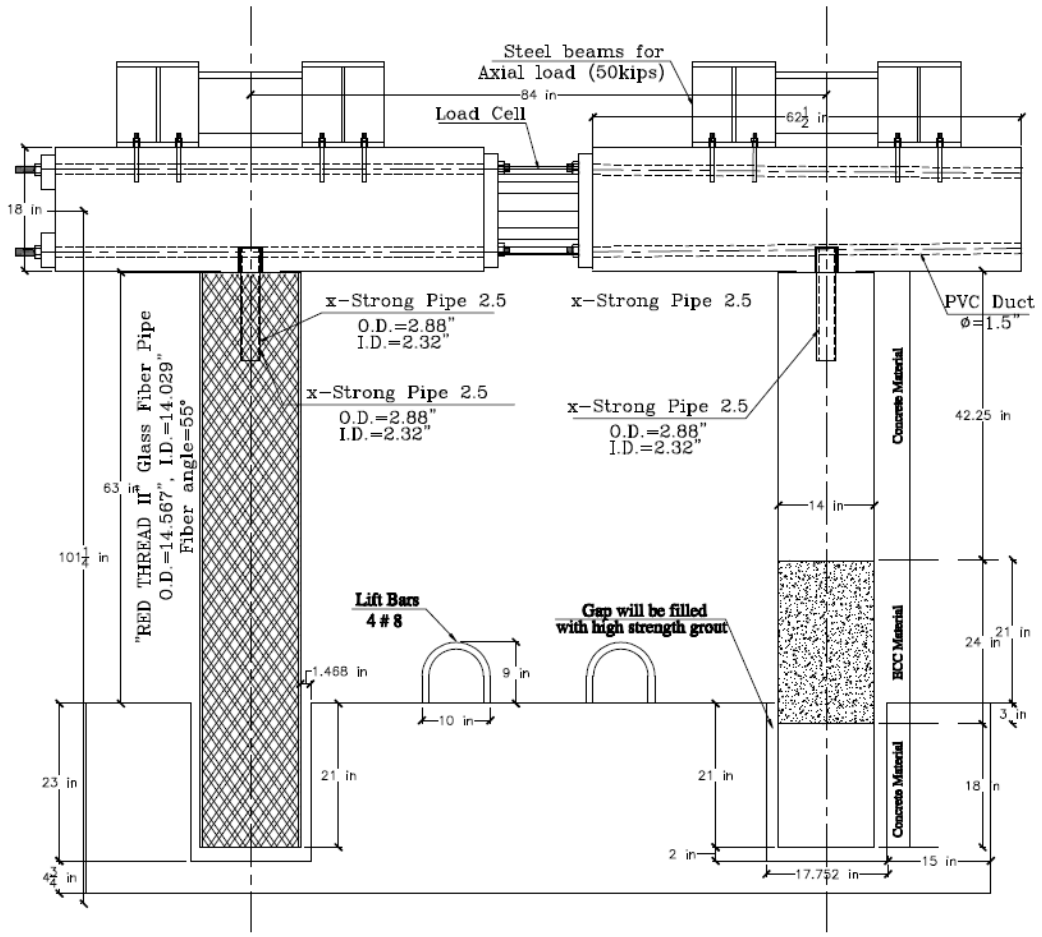


Fig. 2-58. PEFB Bent Detail

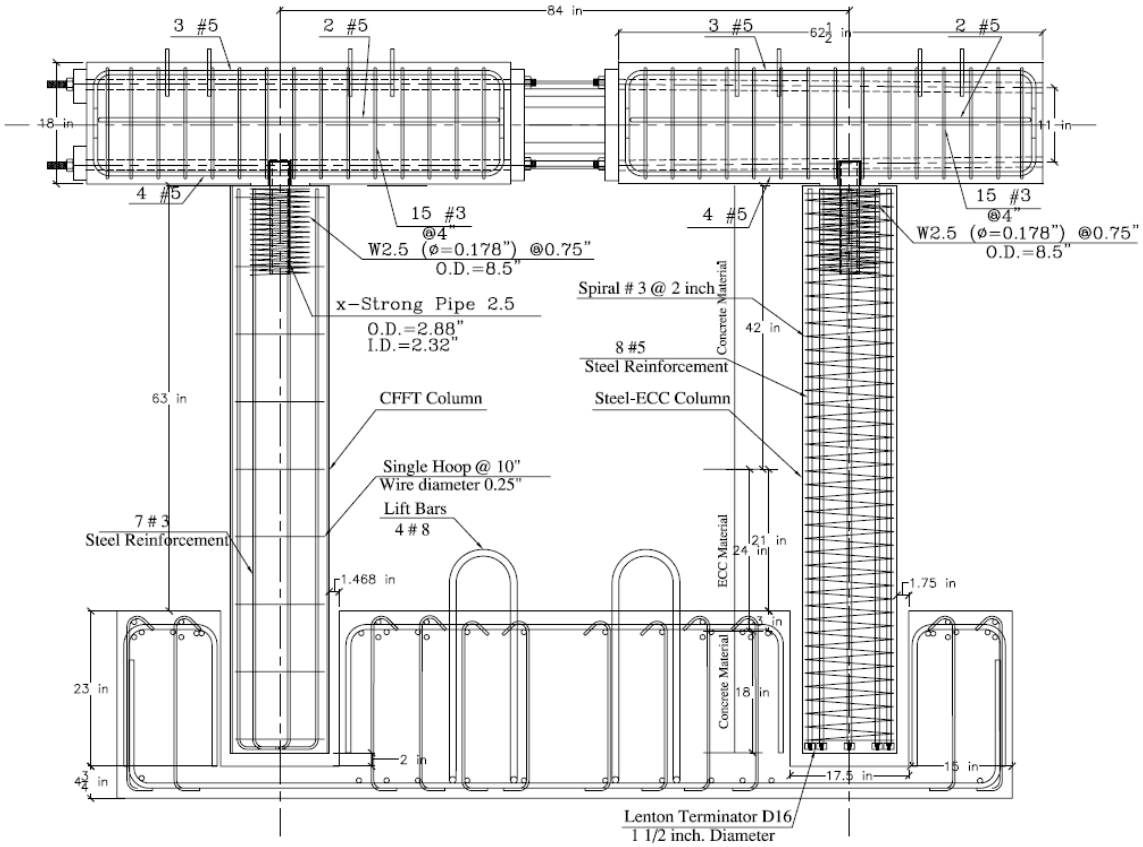


Fig. 2-59. PEFB Reinforcement Detail

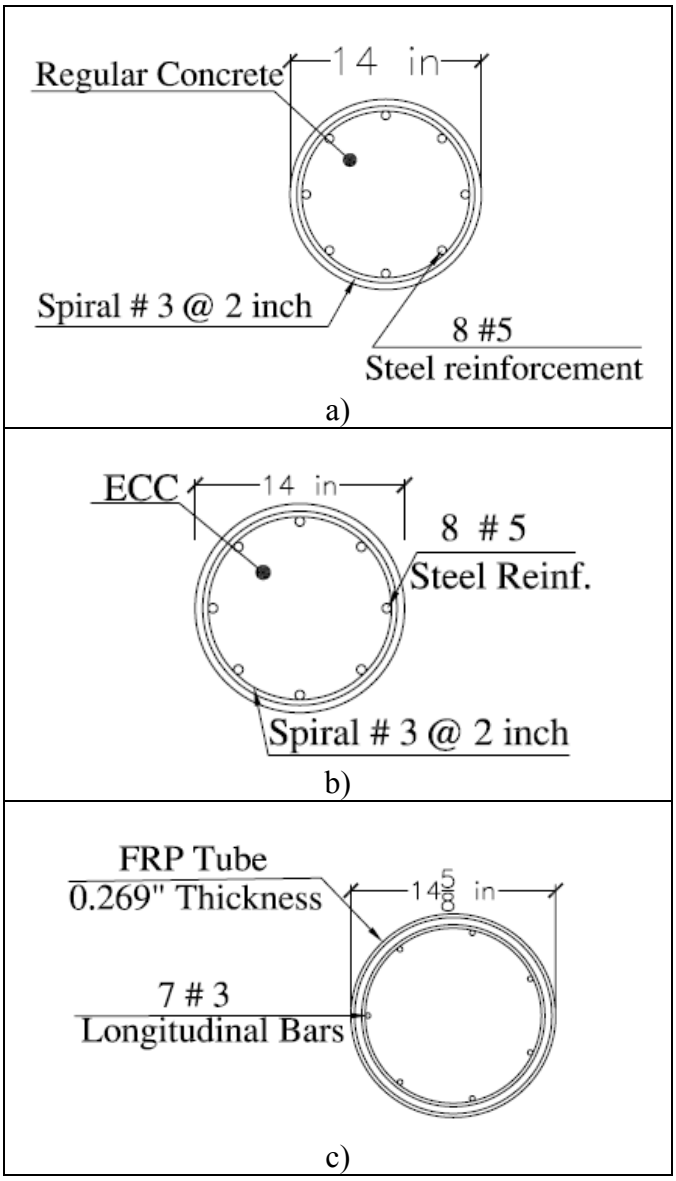


Fig. 2-60. Columns Section Detail, a) RC-ECC Column Top, b) RC-ECC Plastic Hinge, c) FRP Tube Column

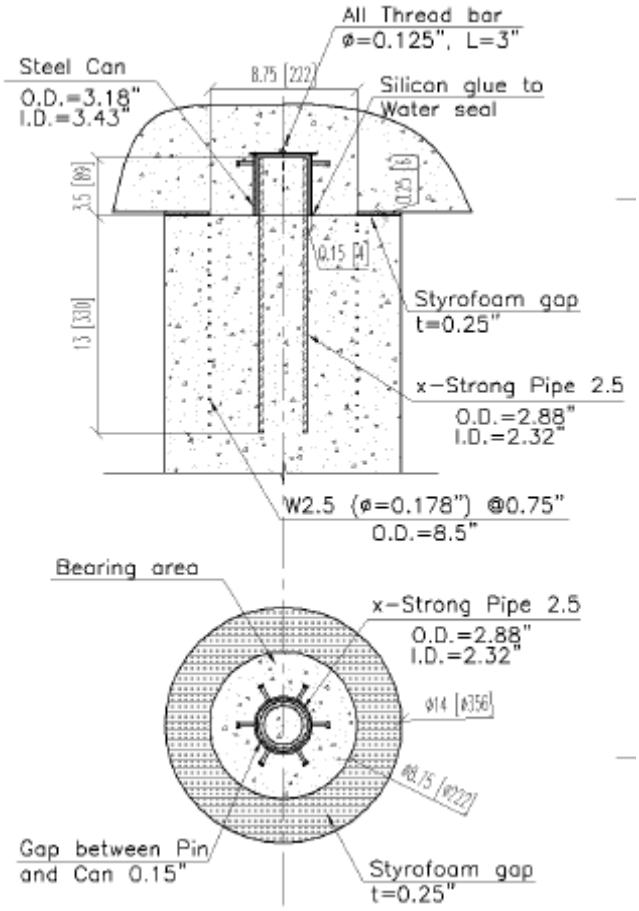


Fig. 2-61. PEFB Pipe-Pin Detail [Zaghi and Saiidi, 2010a]

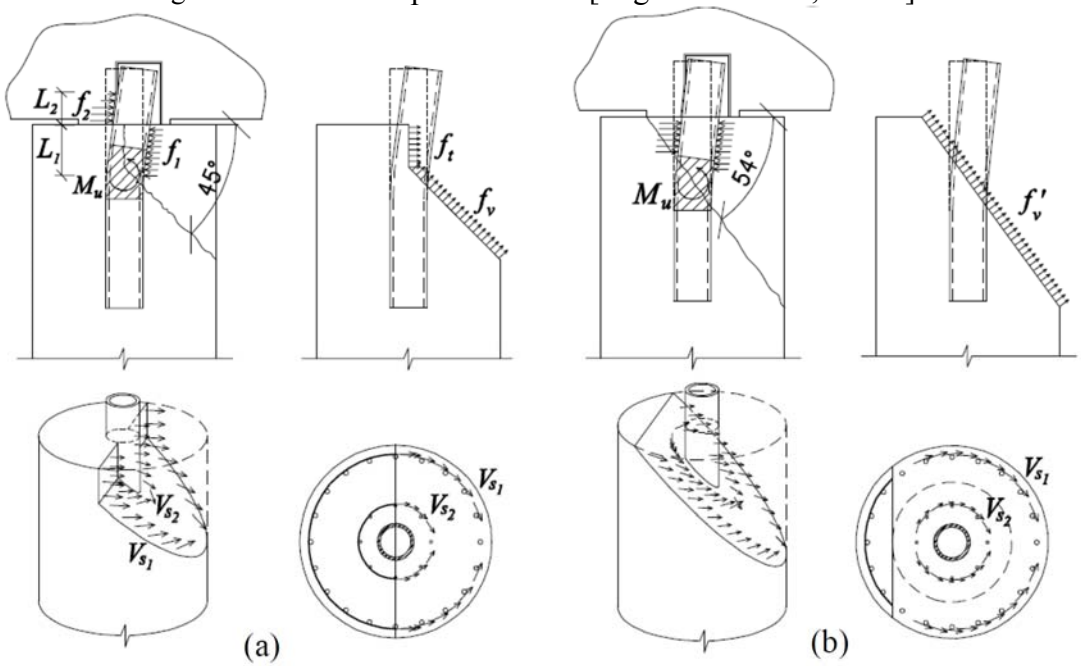


Fig. 2-62. Pipe-Pin Hinges Failure Modes [Zaghi and Saiidi, 2010a]

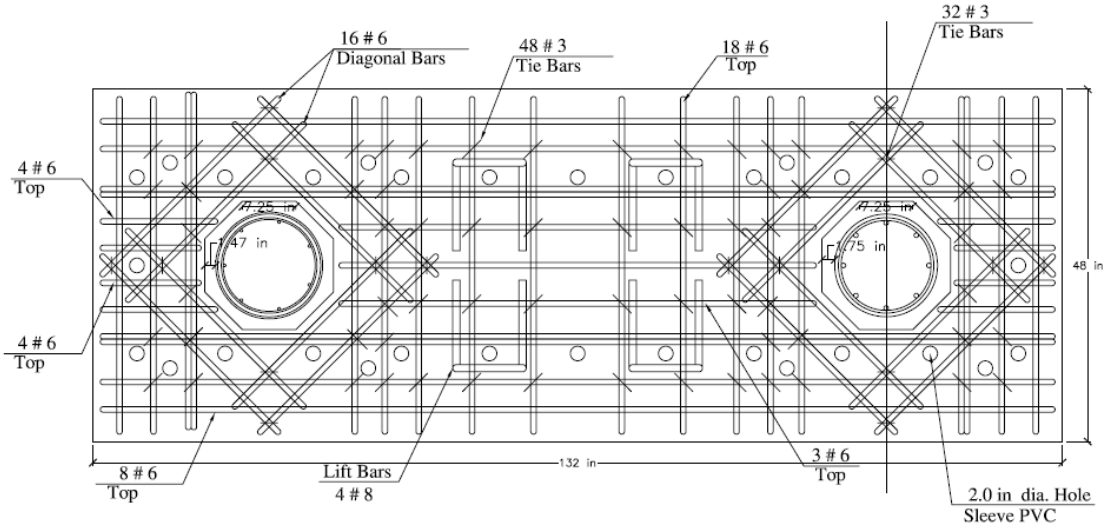


Fig. 2-63. PEFB Footing Reinforcement Detail, Plan View

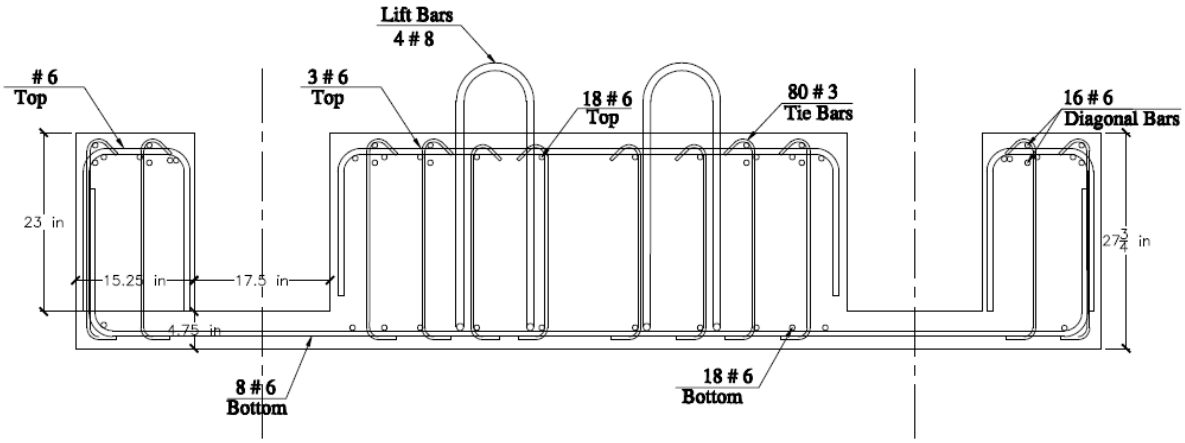


Fig. 2-64. PEFB Footing Reinforcement Detail

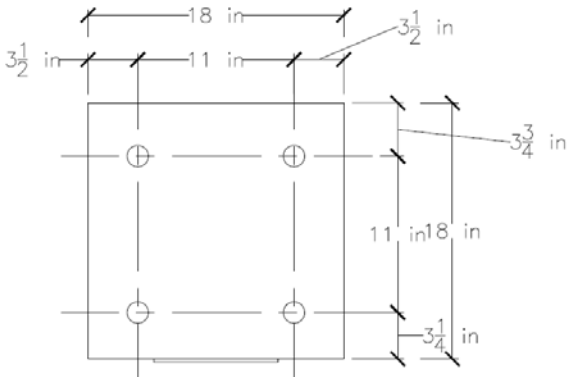


Fig. 2-65. PEFB Cap Beam Detail

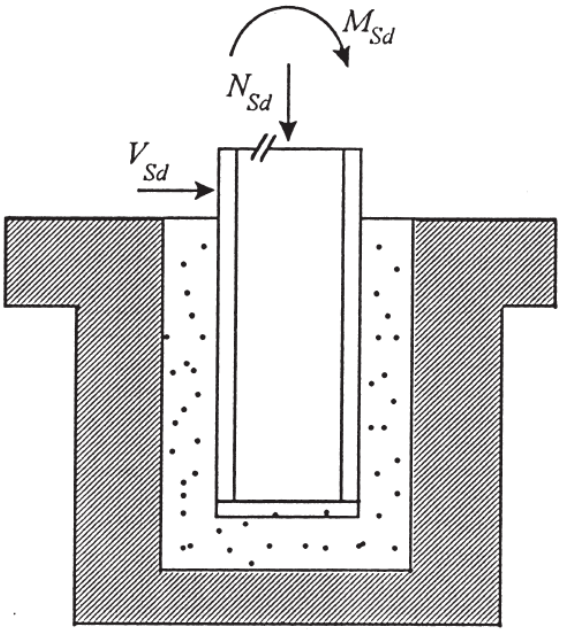


Fig. 2-66. Embedded Column Base [Petrold, et al., 2000b]

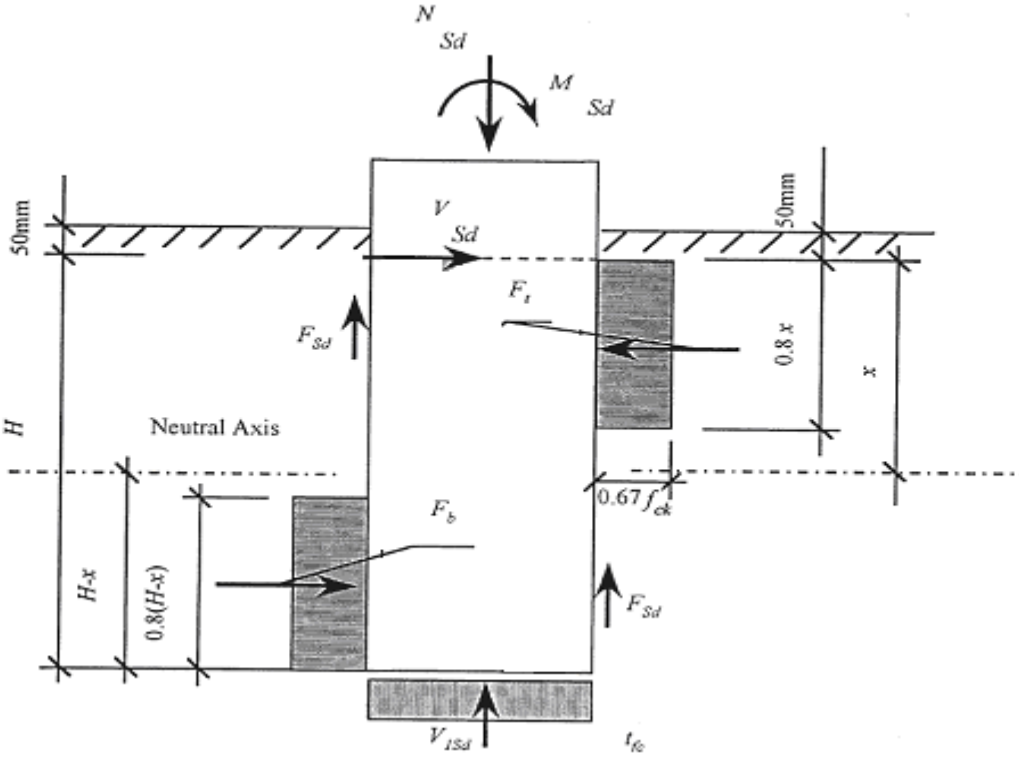


Fig. 2-67. Stress Distribution in Column Base[Petrold, et al., 2000b]

a) b)

Fig. 2-68. Steel Pipe-Pin, a) Filled with Concrete, b) Sat on the Cap Beam

Fig. 2-69. Setting Up Pipe-Pin Hinge Detail on the Cap Beam

Fig. 2-70. Setting Up the Column Cages on the Cap Beam, Up-Side-Down Construction

Fig. 2-71. PEFB Footing before Casting of Concrete

a) b)

Fig. 2-73. PEFB Columns Concrete Casting, a) RC-ECC Column, b) FRP Tube

a) b)

Fig. 2-74. a) RC-ECC Column, b) FRP Tube Column

a) b)

Fig. 2-75. Inserting the Columns in to the Footing a)RC-ECC Column, b) FRP Tube

Fig. 2-76. Pipe Hinge Detail on Top of the Column

Fig. 2-77. Cap Beam Installation

Fig. 2-78. Filling the Opening with Fast Setting Grout

Fig. 2-79. PEFB After Assembly

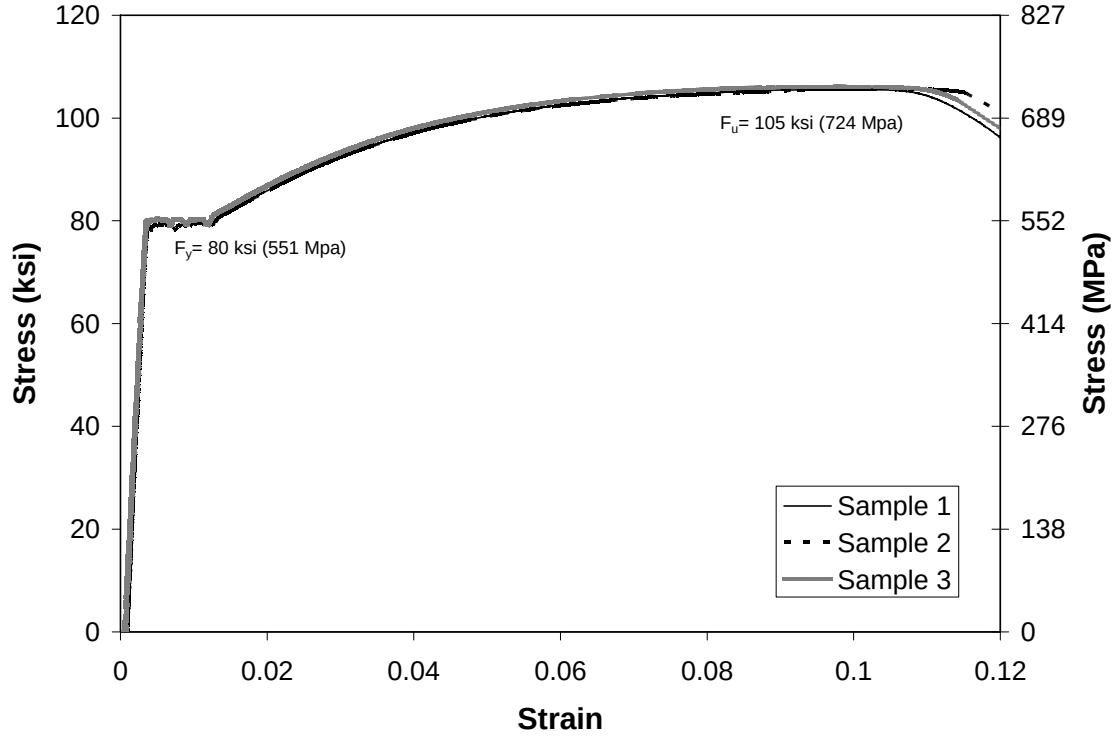


Fig. 2-80. Stress-Strain Behavior of #5 Bars in PEFB

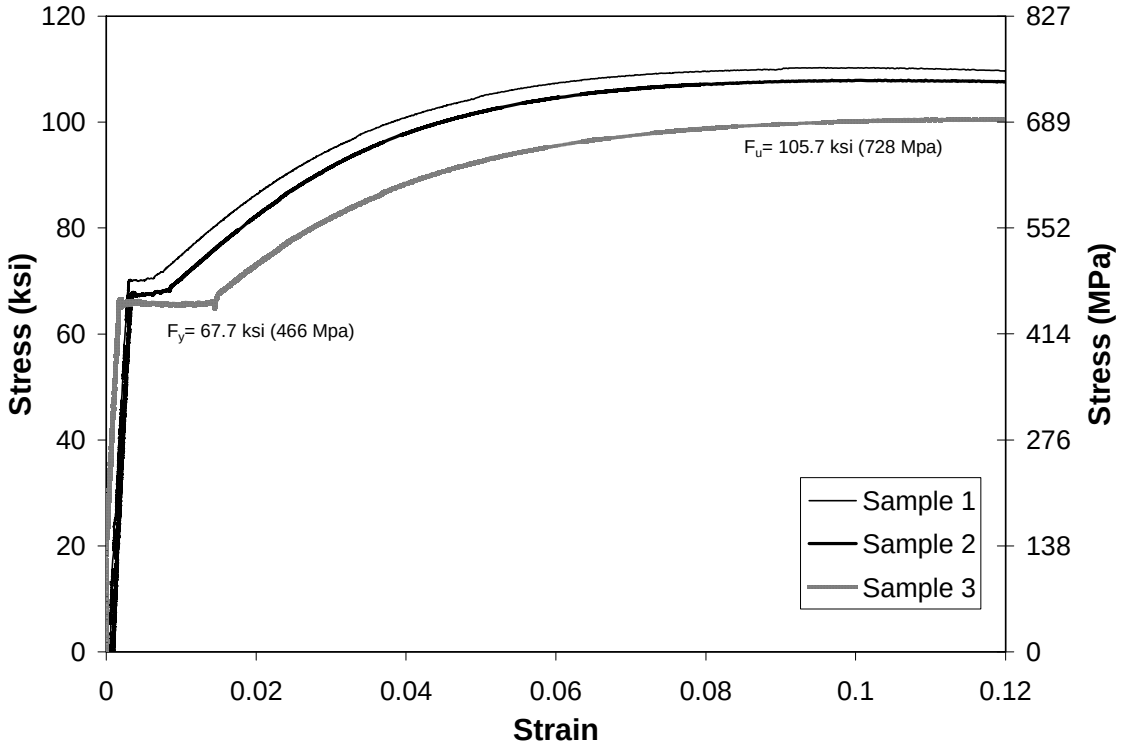
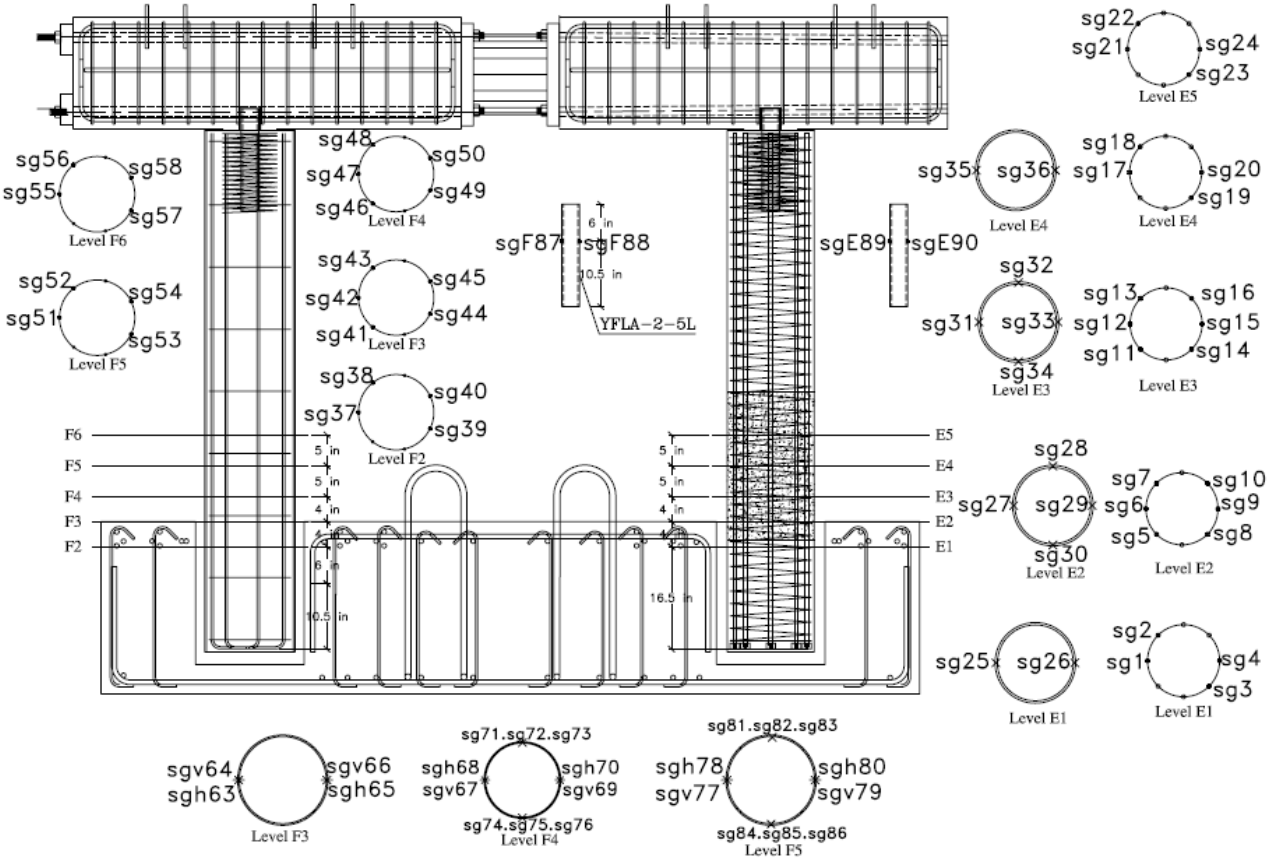


Fig. 2-81. Stress-Strain Behavior of #3 Bars in PEFB



on the FRP Tube

Fig. 2-82. PEFB Strain Gauge Plan

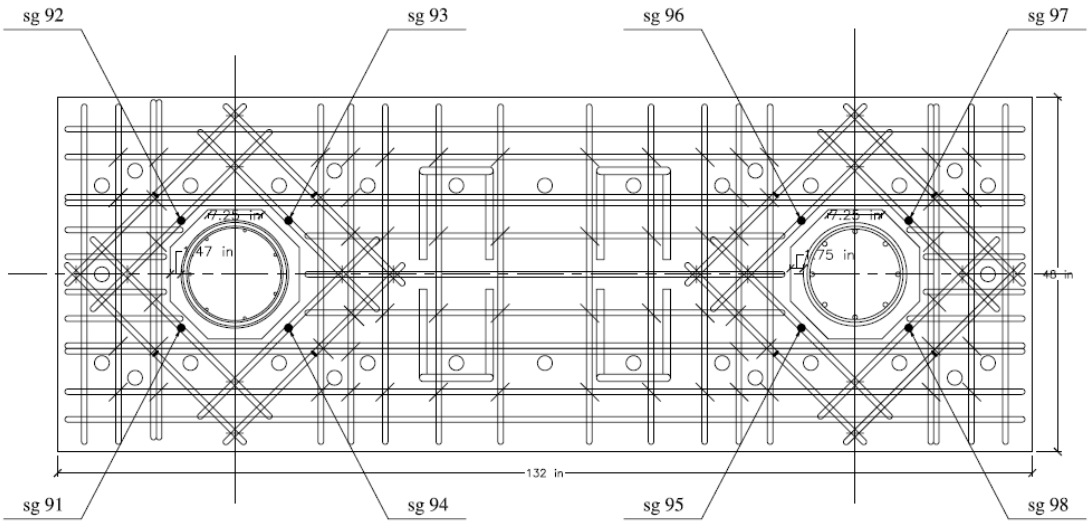


Fig. 2-83. PEFB Strain Gauge Plan in Footing

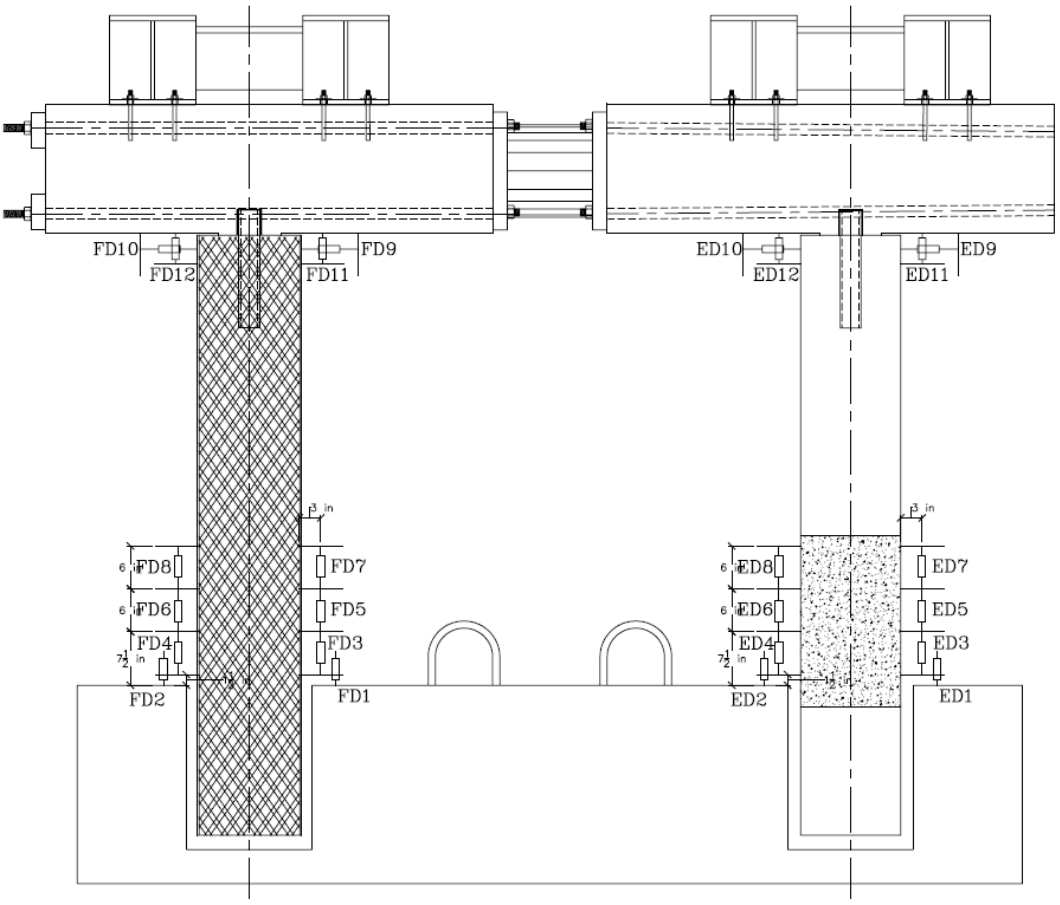


Fig. 2-84. PEFB Novotechnik Plan

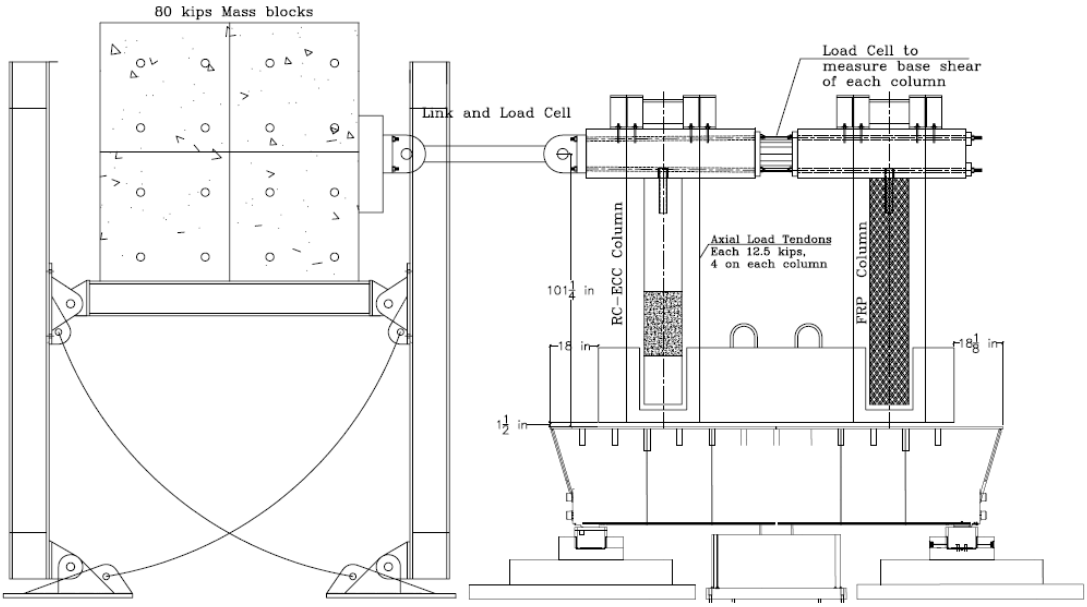


Fig. 2-85. PEFB Shake Table Test Set up

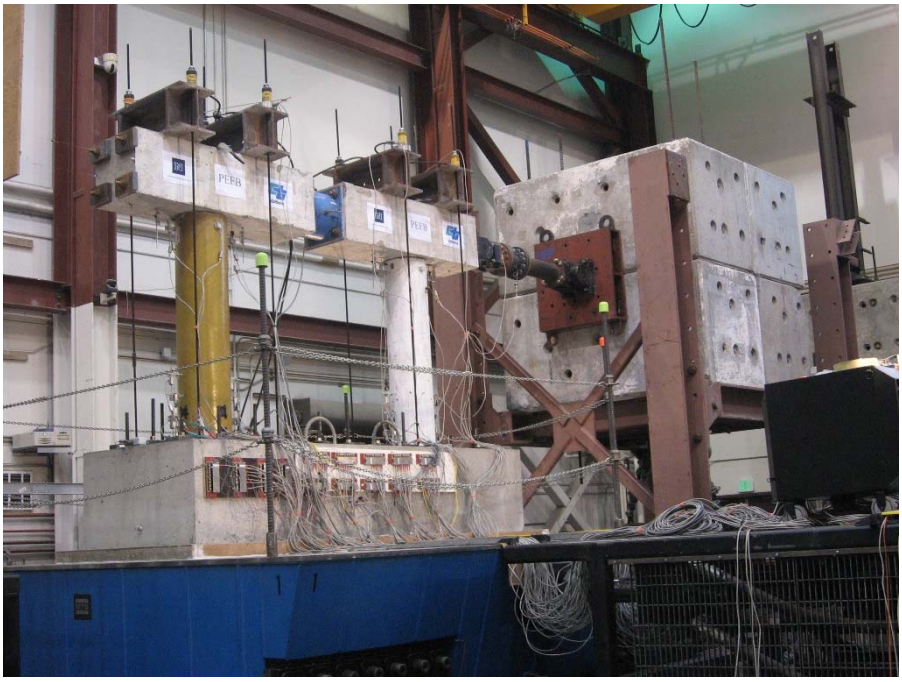
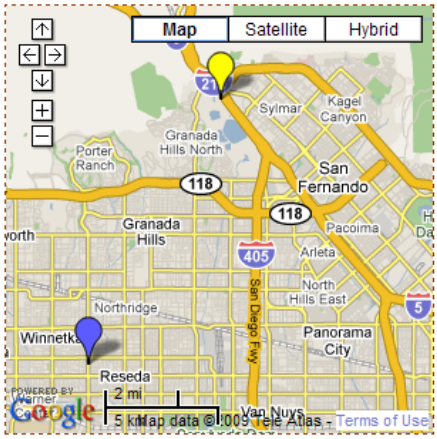


Fig. 2-86. PEFB on the Shake Table

Record Number NGA1084



Earthquake: Northridge-01 1994-01-17 12:31
Magnitude: 6.69
Mo: 1.2162E+26
Mechanism: 2
Hypocenter Latitude: 34.2057 | Longitude: -118.554 | Depth: 17.5 (km)
Fault Rupture Length: 18.0 (km) | Width: 24.0 (km)
Average Fault Displacement: 78.6 (cm)
Fault Name: Northridge Blind Thrust
Slip Rate: 1.50 (mm/yr)

Station: DWP 74 Sylmar - Converter Sta
Latitude: 34.3110 | Longitude: -118.490
Geomatrix 1: I | Geomatrix 2: H | Geomatrix 3: D
Preferred Vs30: 251.20 (m/s) | Alt Vs30:
Instrument location:

Epicentral Distance: 13.11 (km) | Hypocentral Distance: 21.87 (km) | Joyner-Boore Distance: 0.00 (km)
Campbell R Distance: 5.35 (km) | RMS Distance: 12.73 (km) | Closest Distance: 5.35 (km)
PGA: 0.7123 (g)
PGV: 109.3800 (cm/sec)
PGD: 52.3500 (cm)

Fig. 2-87. Record Station of the Ground Motion

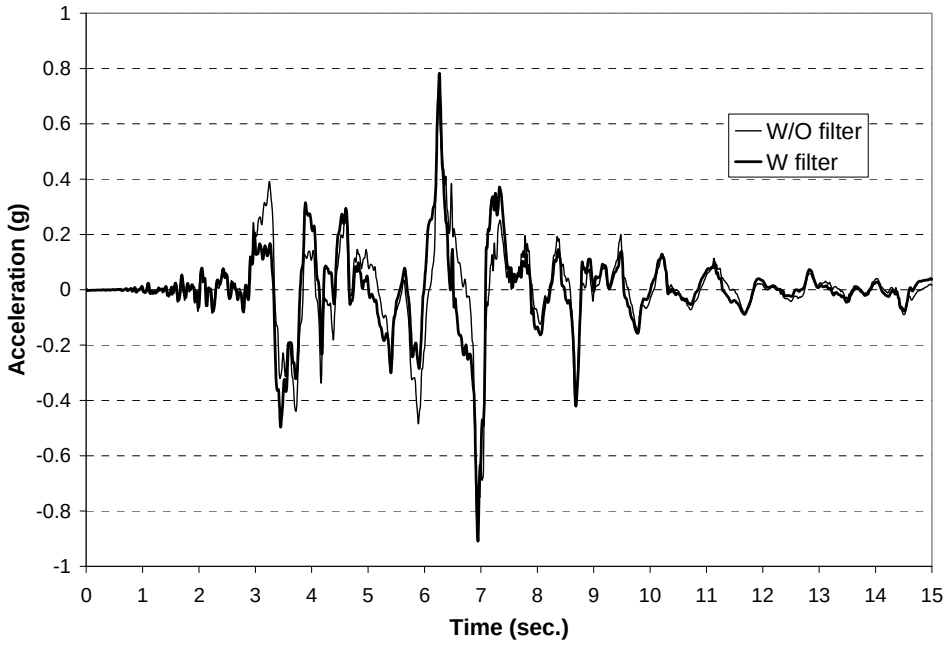
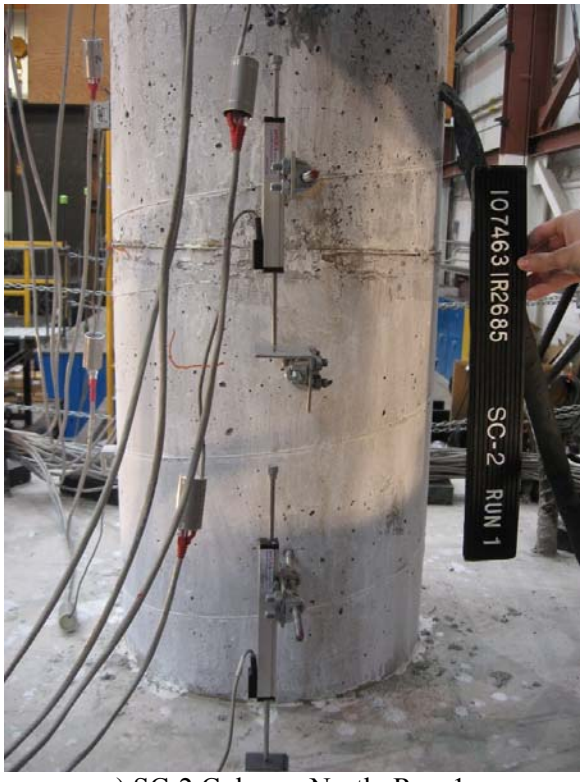
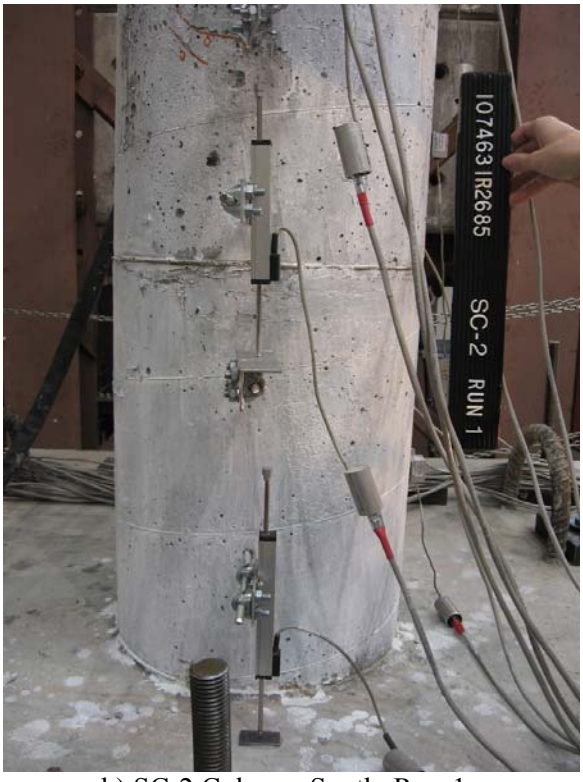


Fig. 2-88. Acceleration History of the Ground Motion

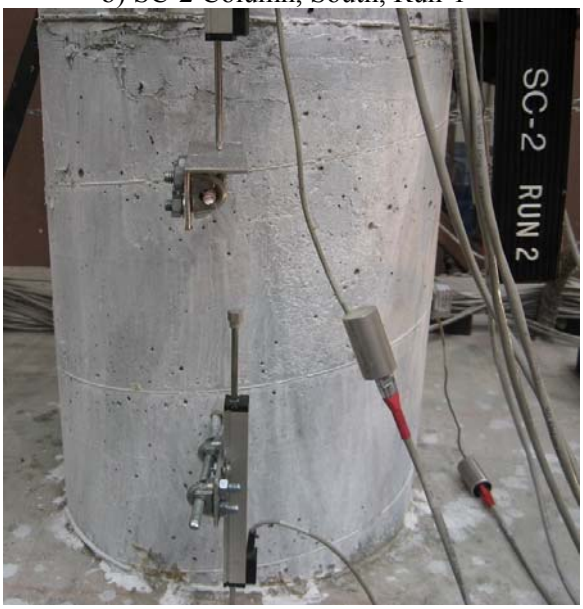


a) SC-2 Column, North, Run-1



b) SC-2 Column, South, Run-1

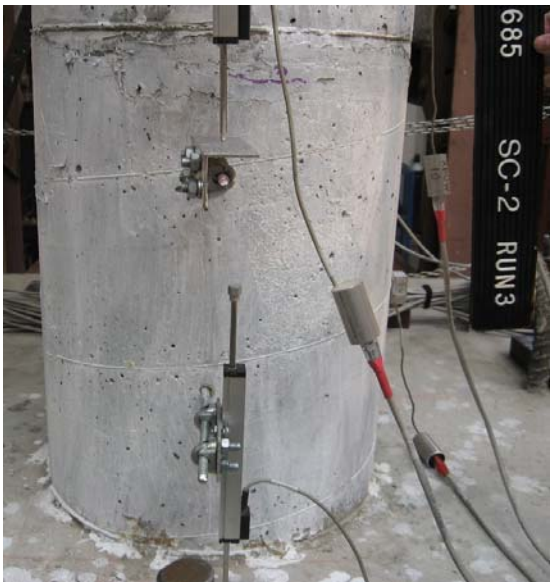
c) SC-2 Column, North, Run-2



d) SC-2 Column, South, Run-2

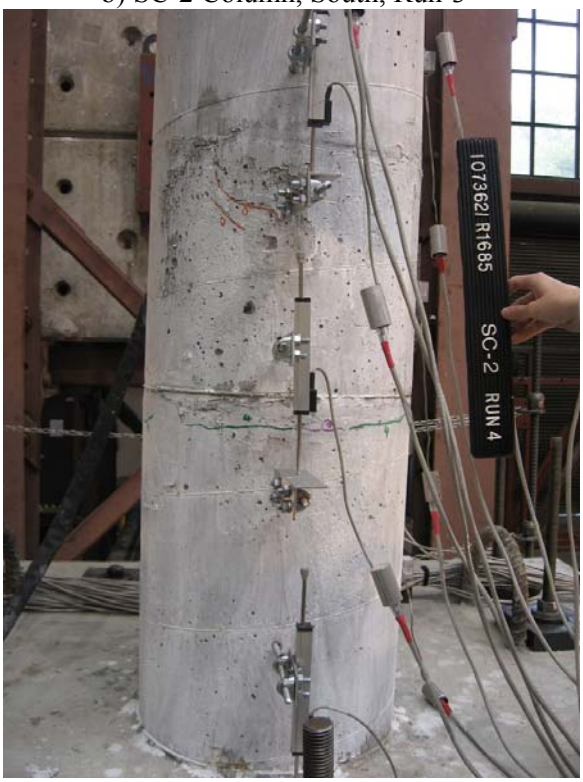
Fig. 3-1. Damage Progression Photographs for SC-2 Column, Bottom, Run 1 and 2

a) SC-2 Column, North, Run-3



b) SC-2 Column, South, Run-3

c) SC-2 Column, North, Run-4



d) SC-2 Column, South, Run-4

Fig. 3-2. Damage Progression Photographs for SC-2 Column, Bottom, Run 3 and 4

a) SC-2 Column, North, Run-5

b) SC-2 Column, South, Run-5

c) SC-2 Column, North, Run-6

d) SC-2 Column, South, Run-6

Fig. 3-3. Damage Progression Photographs for SC-2 Column, Bottom, Run 5 and 6

a) SC-2 Column, North, Run-7 b) SC-2 Column, South, Run-7

Fig. 3-4. Damage Progression Photographs for SC-2 Column, Bottom, Run 7

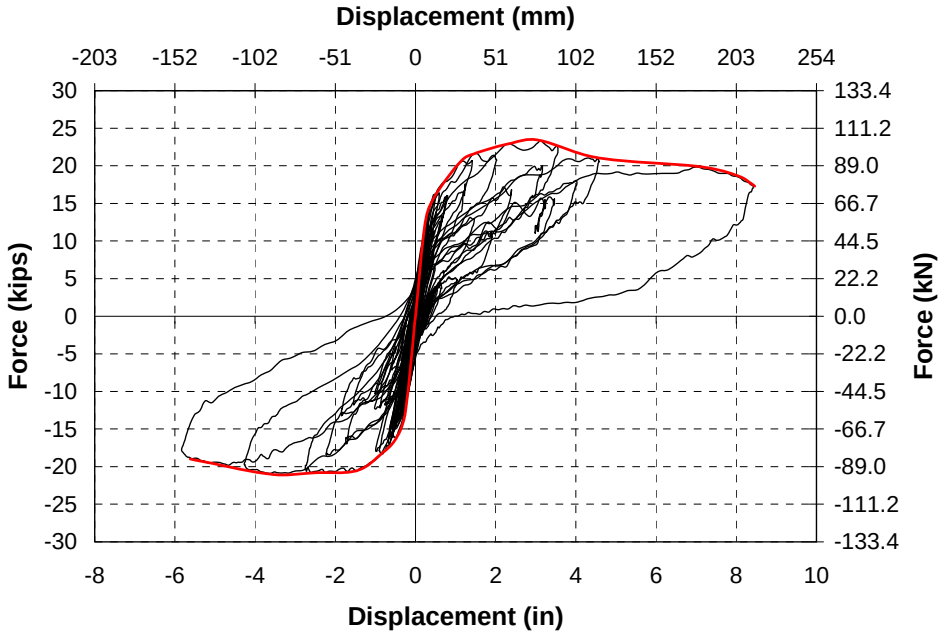


Fig. 3-5. Accumulated Force-Displacement Hysteresis Curve for SC-2

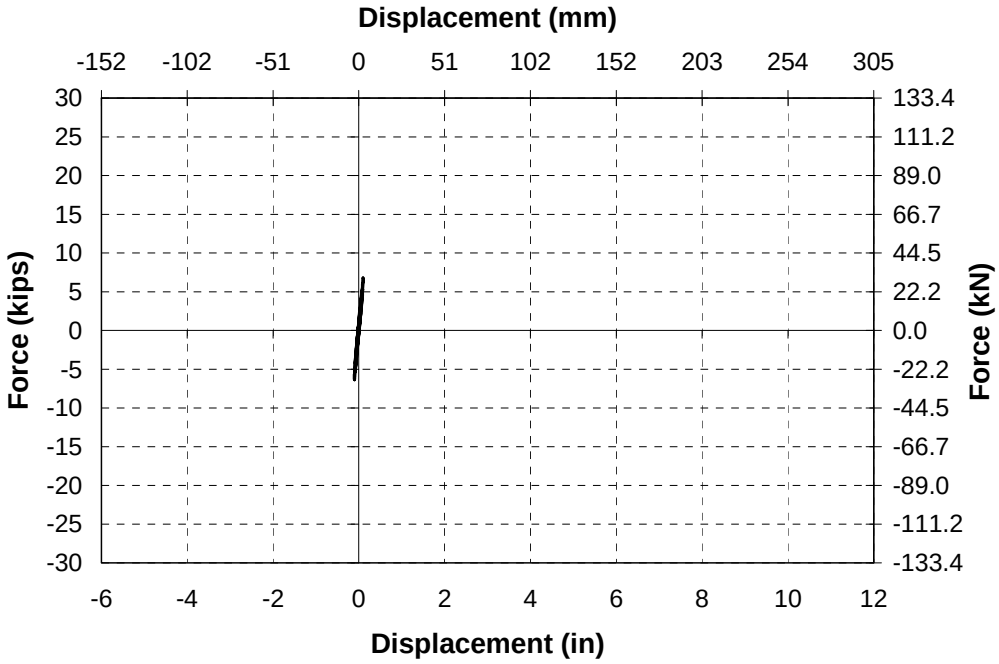


Fig. 3-6. Force-Displacement Hysteresis Curve for Run 1 in SC-2

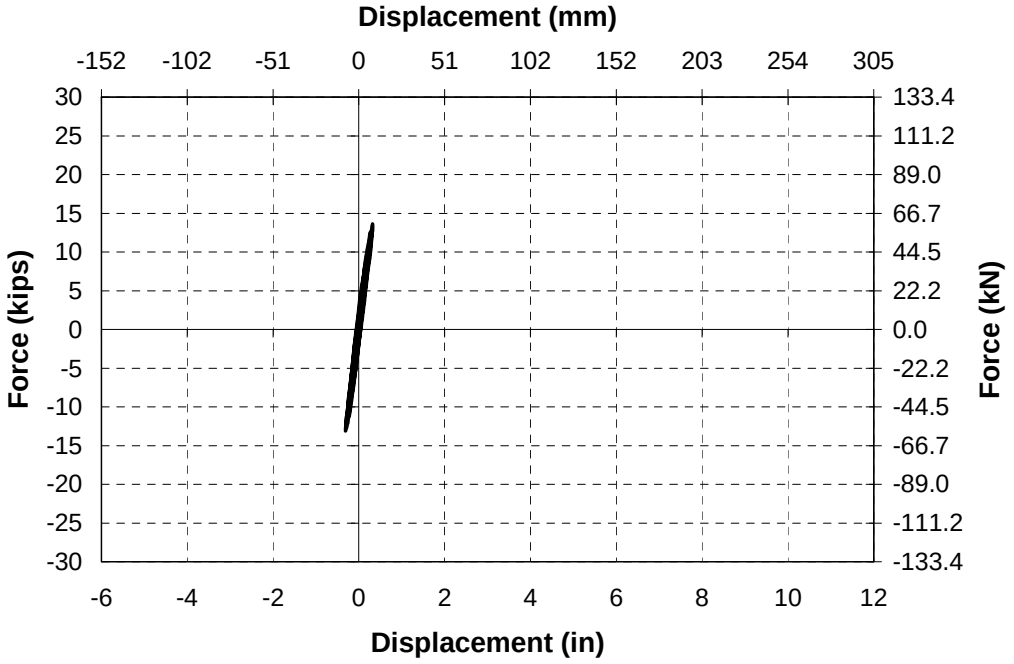


Fig. 3-7. Force-Displacement Hysteresis Curve for Run 2 in SC-2

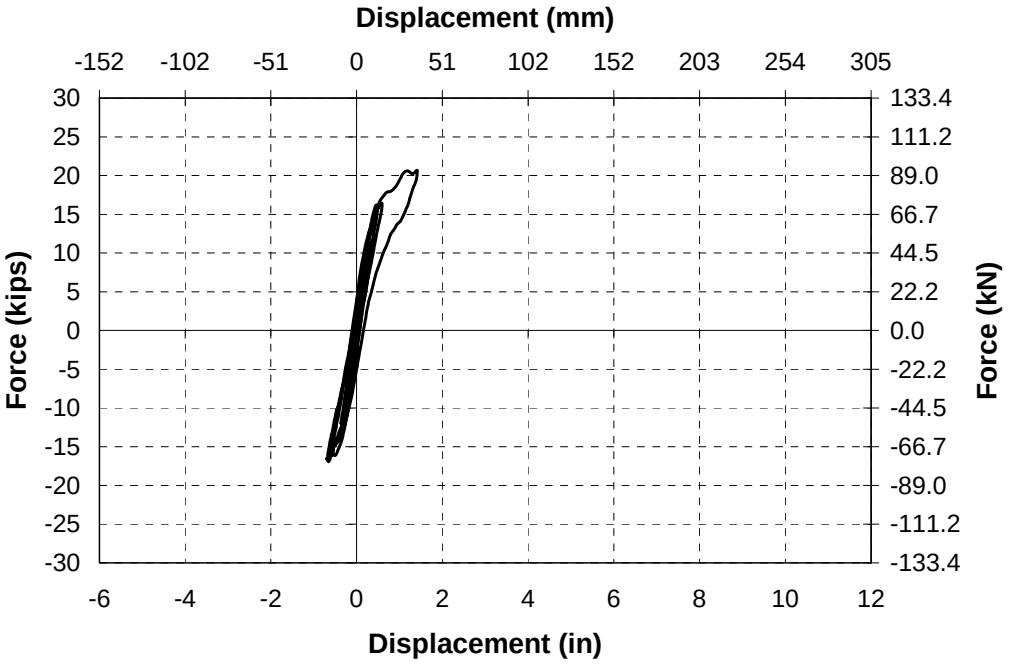


Fig. 3-8. Force-Displacement Hysteresis Curve for Run 3 in SC-2

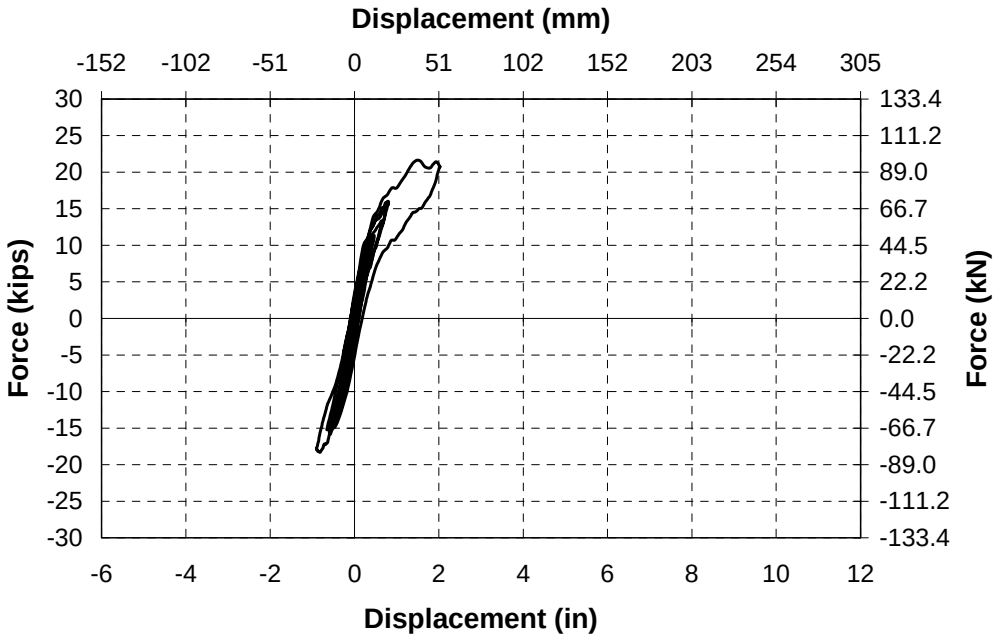


Fig. 3-9. Force-Displacement Hysteresis Curve for Run 4 in SC-2

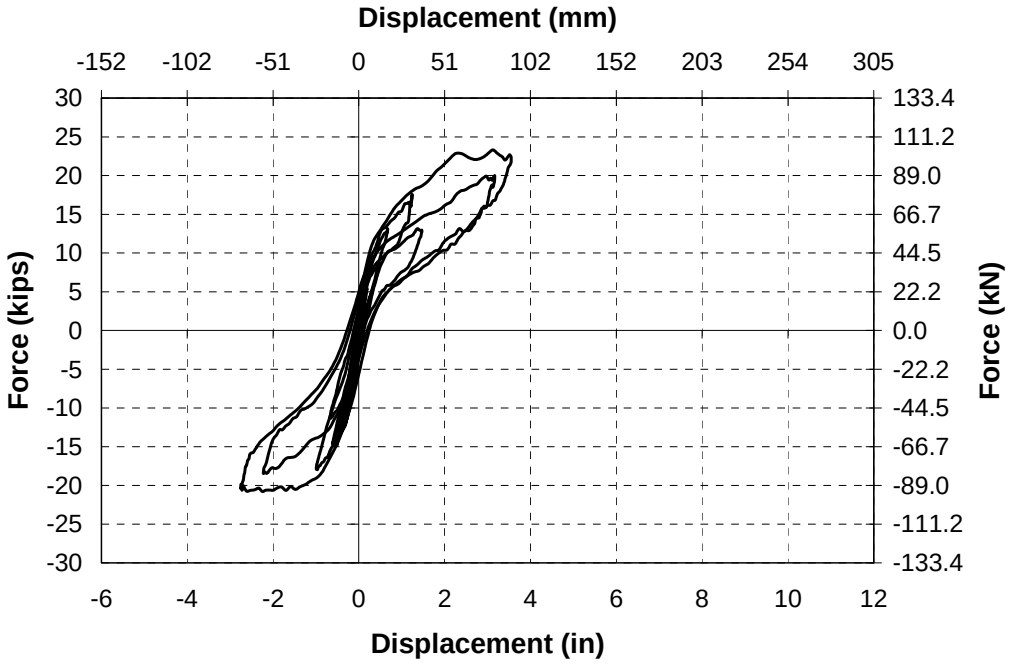


Fig. 3-10. Force-Displacement Hysteresis Curve for Run 5 in SC-2

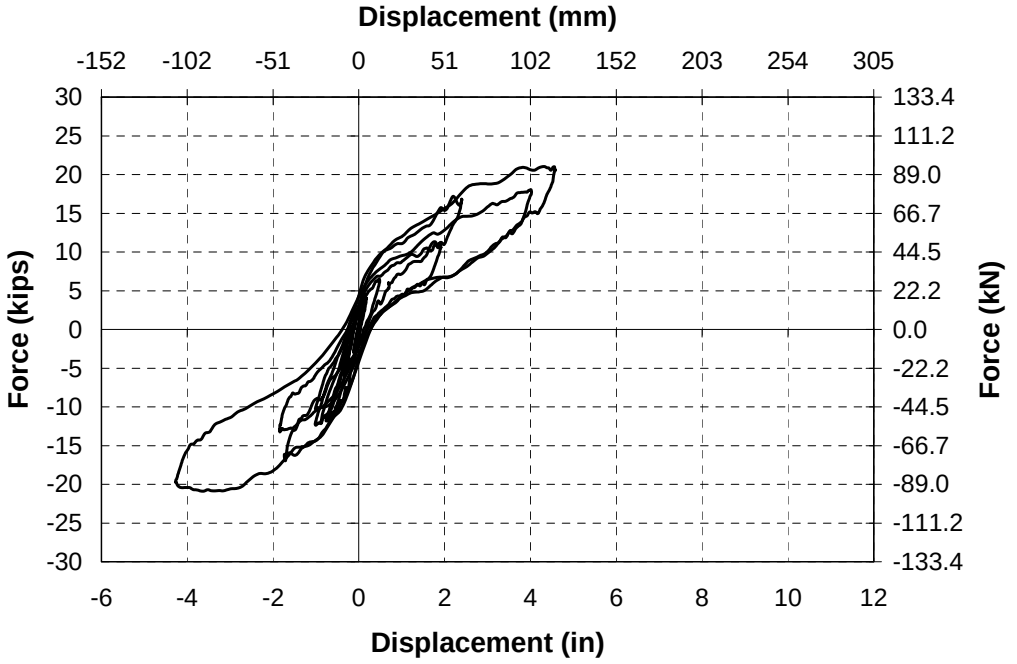


Fig. 3-11. Force-Displacement Hysteresis Curve for Run 6 in SC-2

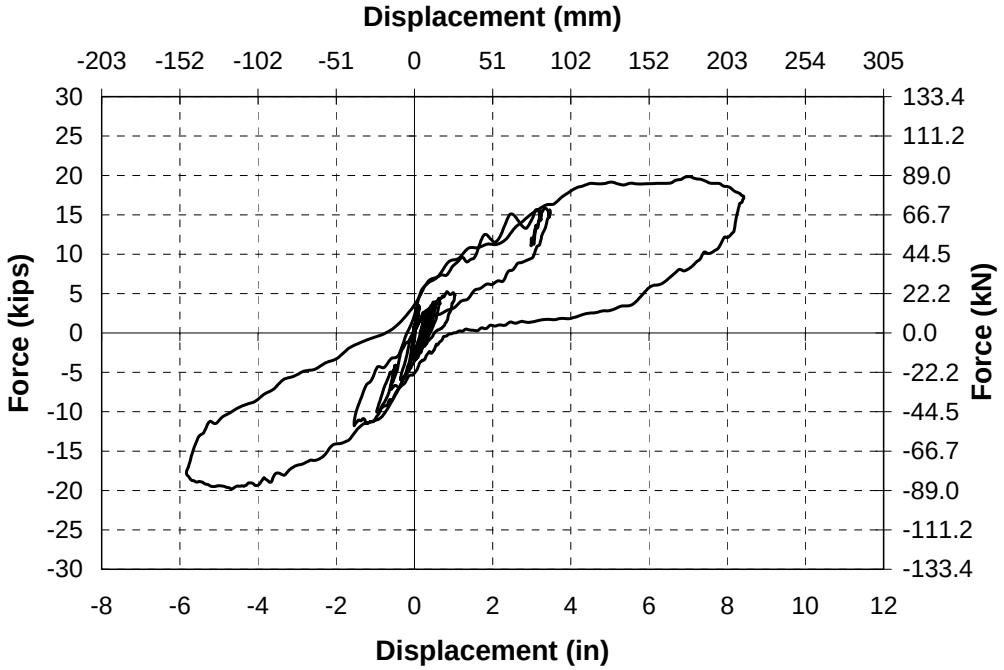


Fig. 3-12. Force-Displacement Hysteresis Curve for Run 7 in SC-2

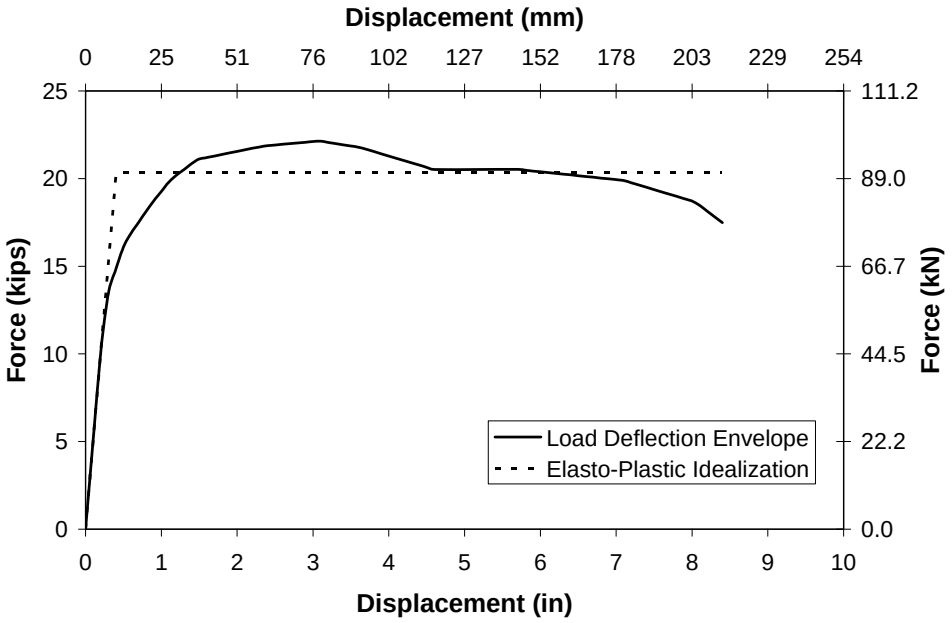


Fig. 3-13. Backbone Curve of SC-2

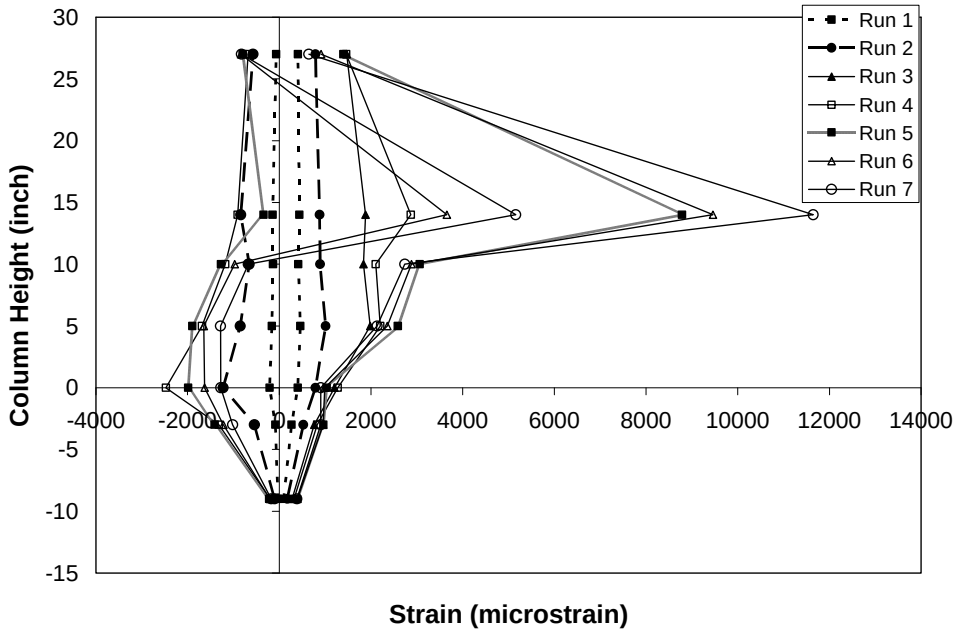


Fig. 3-14. The Max. and Min. Long. Strain Profile of the SC-2

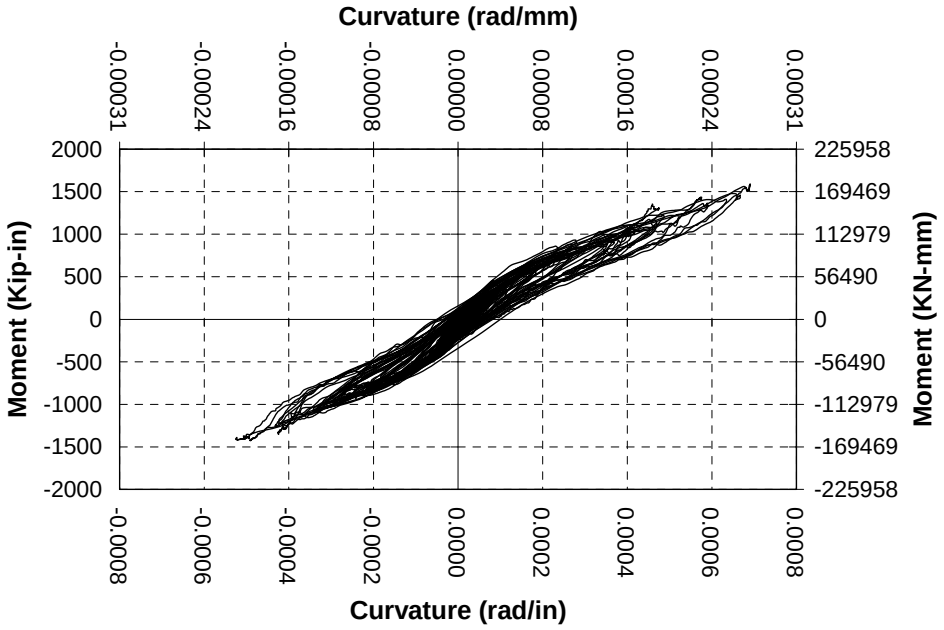


Fig. 3-15. Accumulated Moment Curvature at the First Level in SC-2

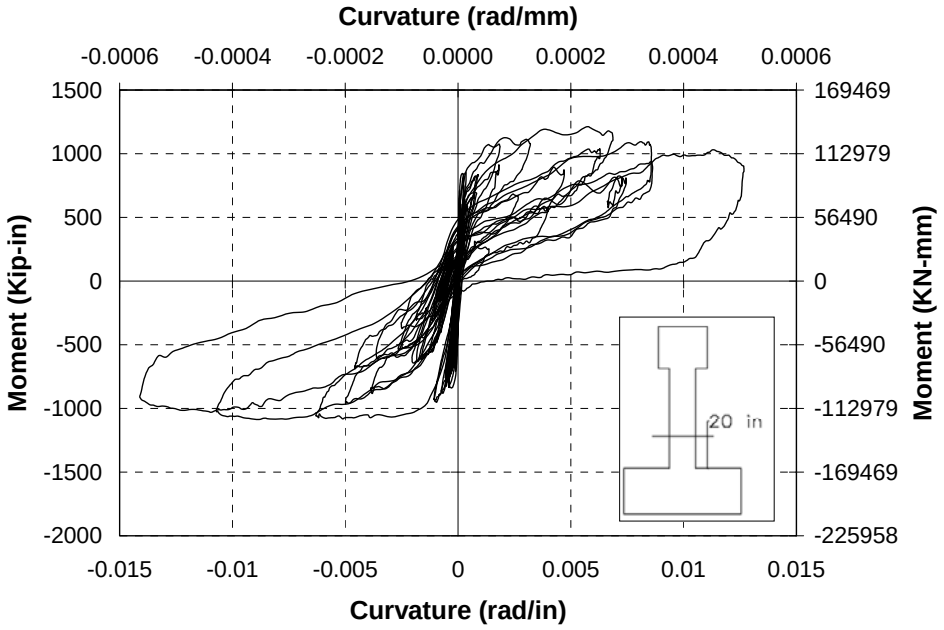


Fig. 3-16. Accumulated Moment Curvature at the Second Level in SC-2

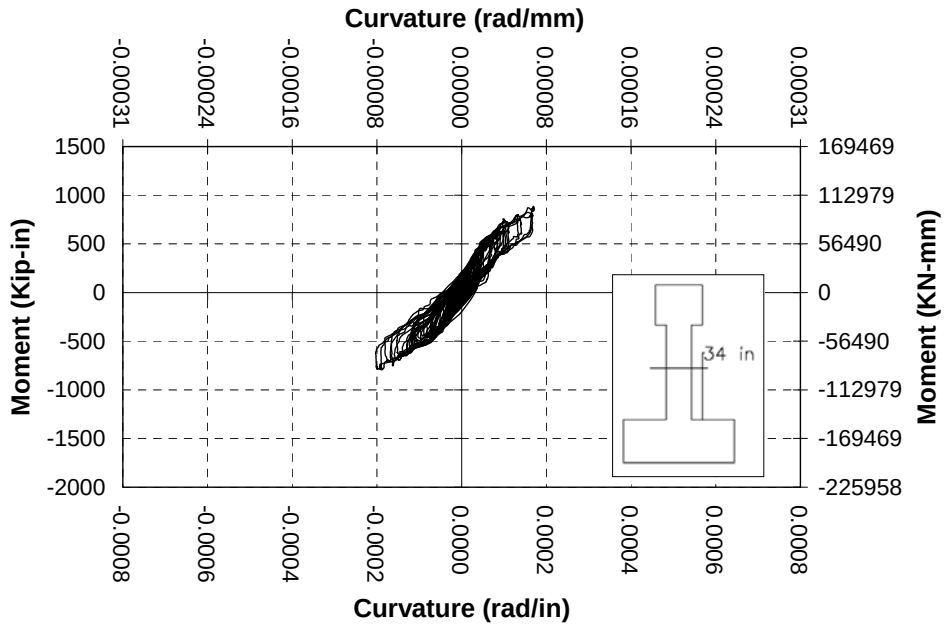


Fig. 3-17. Accumulated Moment Curvature at the Third Level in SC-2

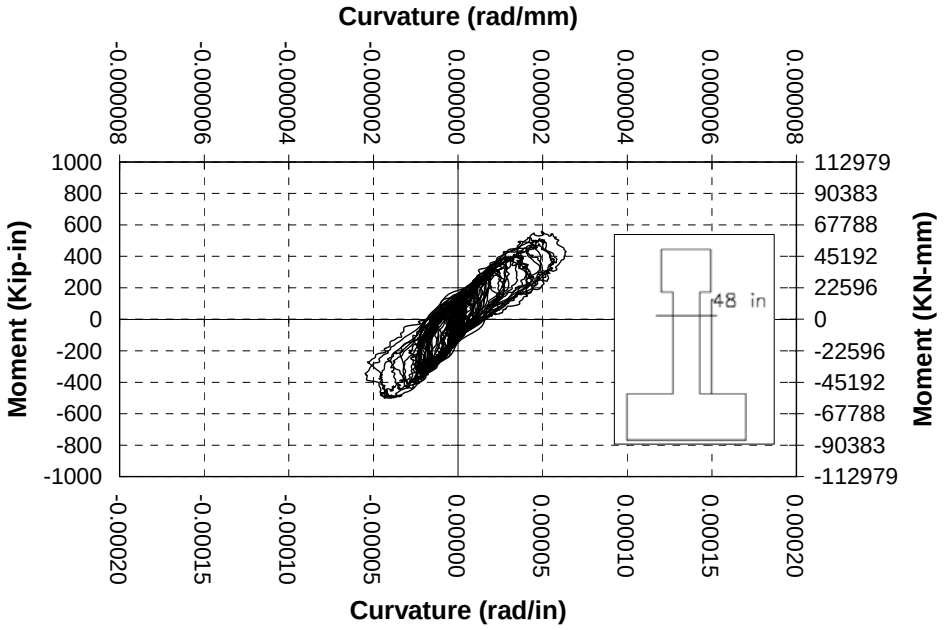


Fig. 3-18. Accumulated Moment Curvature at the Fourth Level in SC-2

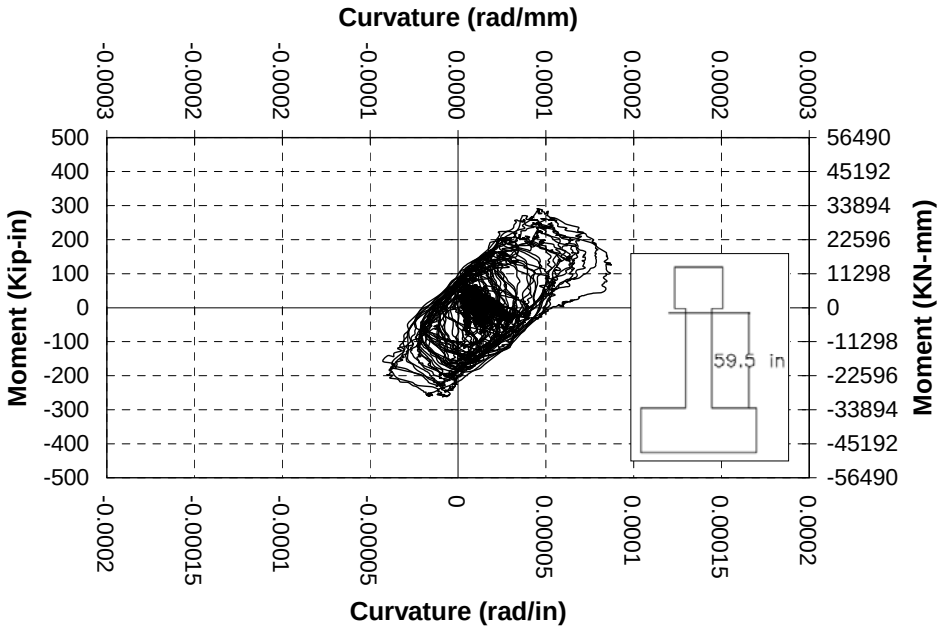


Fig. 3-19. Accumulated Moment Curvature at the Fifth Level in SC-2

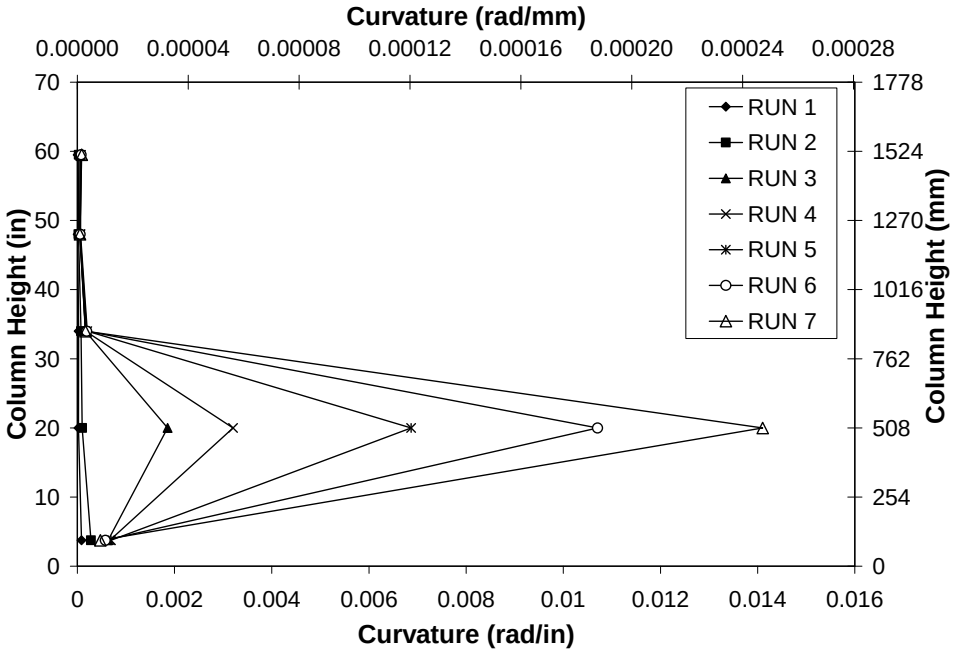


Fig. 3-20. Curvature Profile for SC-2

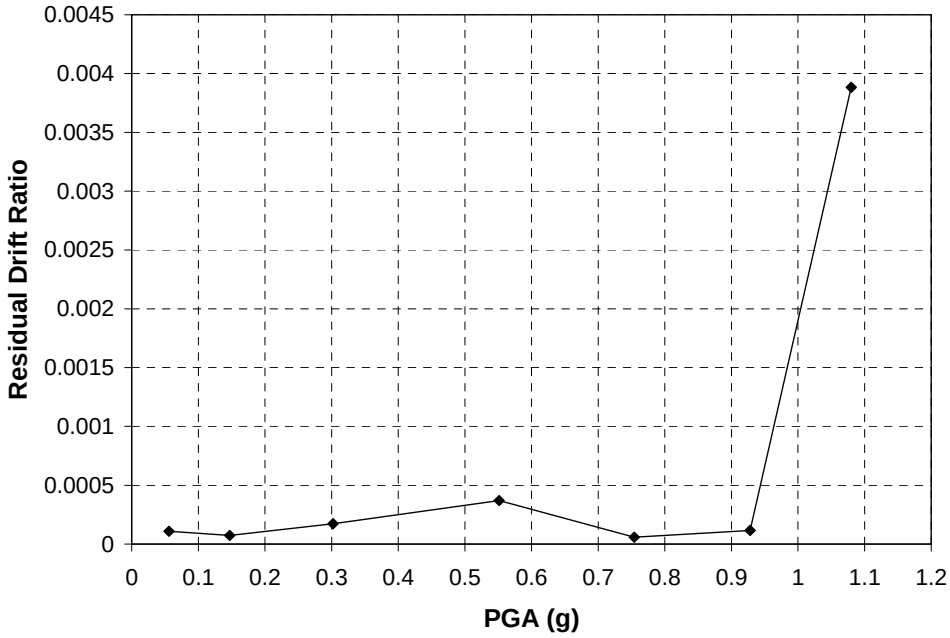


Fig. 3-21. Residual Drift Ratio vs. PGA in SC-2

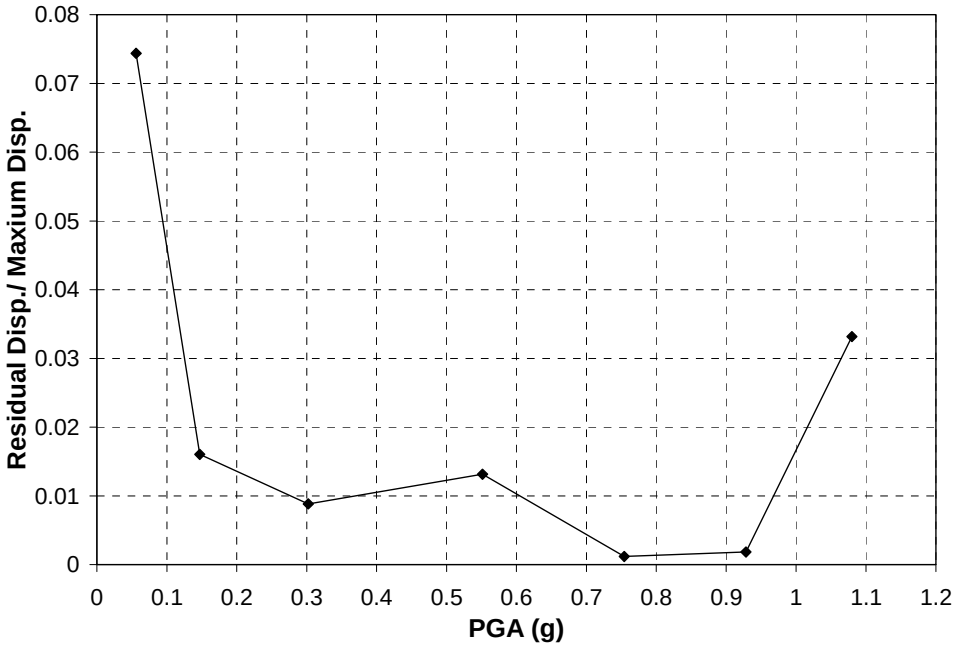


Fig. 3-22. Residual Disp. / Max. Disp. vs. PGA in SC-2

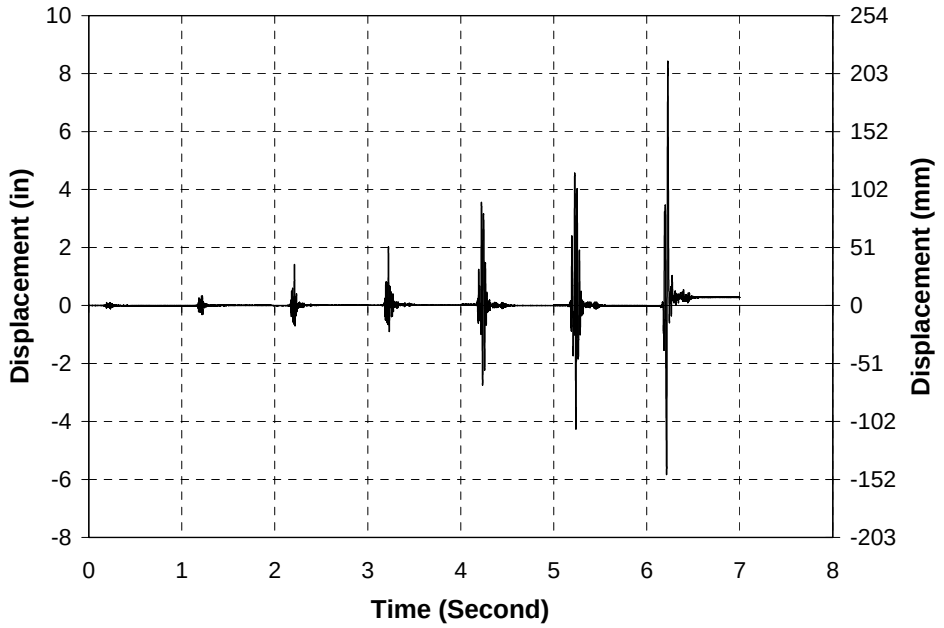


Fig. 3-23. Displacement History in Column SC-2

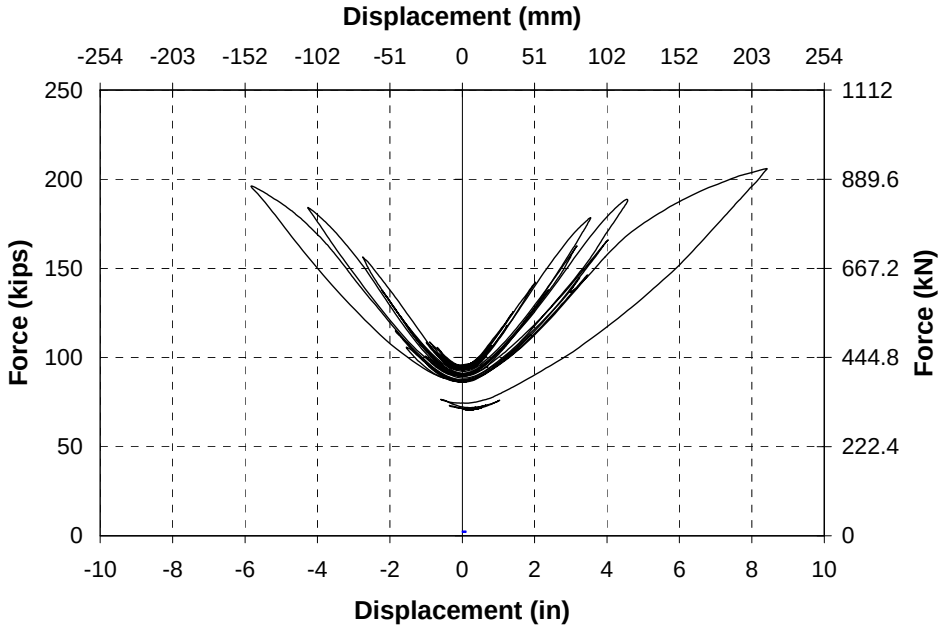


Fig. 3-24. Unbonded PT Rod Force vs. Displacement in SC-2

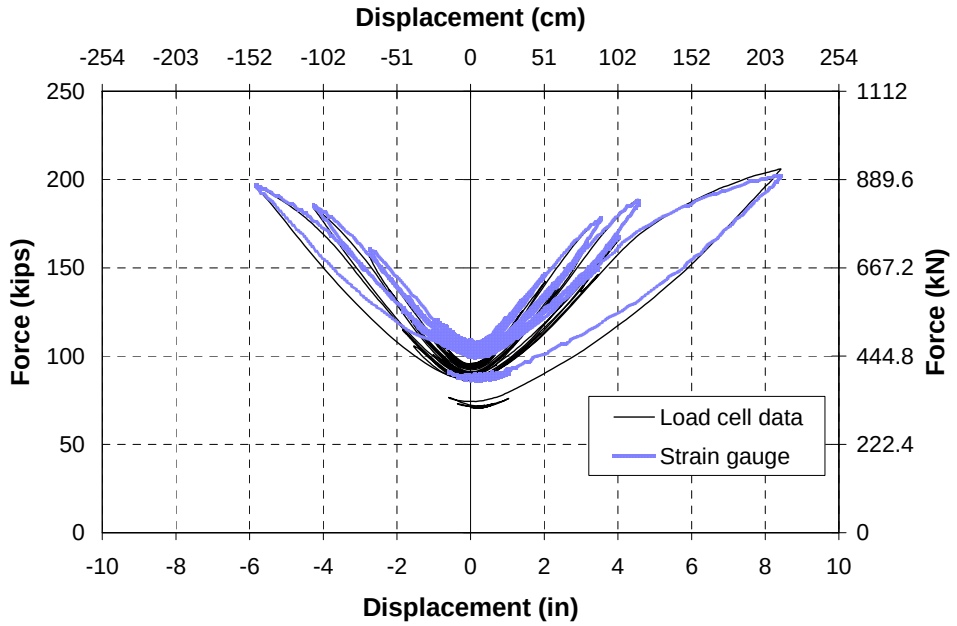


Fig. 3-25. Comparison of Unbonded PT Rod Force Measured by Load Cell and Strain Gauges in SC-2

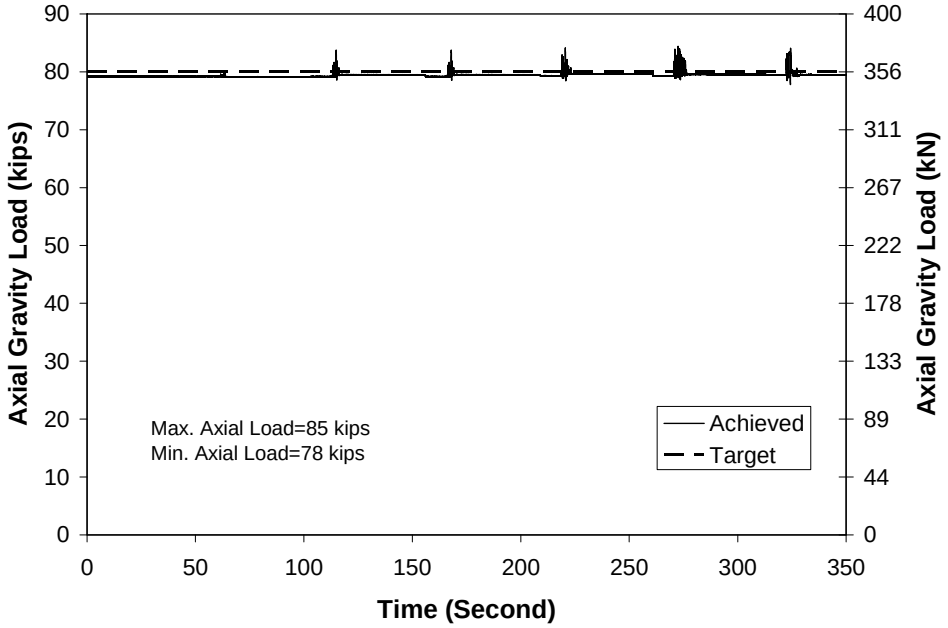


Fig. 3-26. Axial Gravity Load History on SC-2

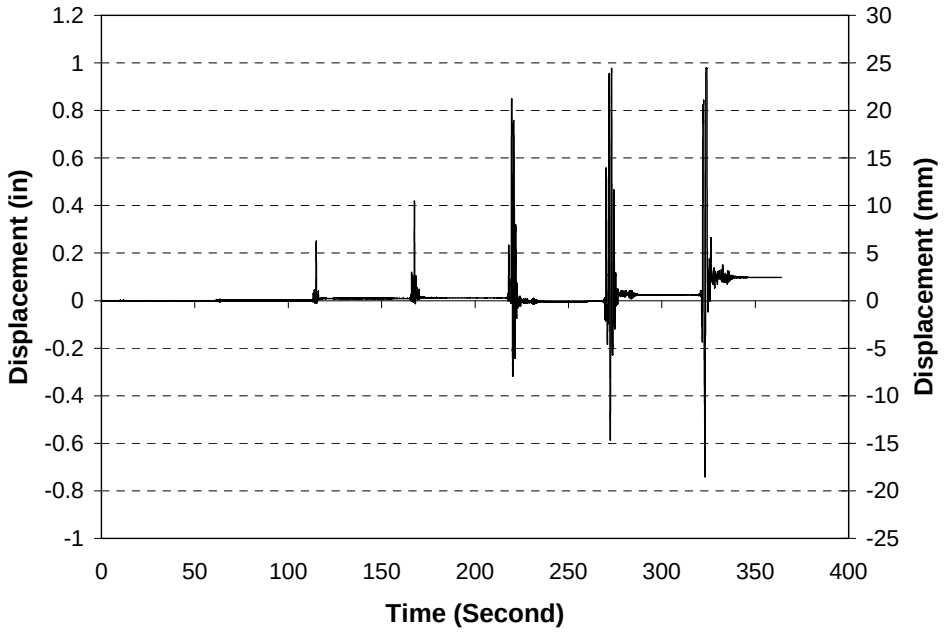


Fig. 3-27. History of Segment Separations at South Side of the SC-2

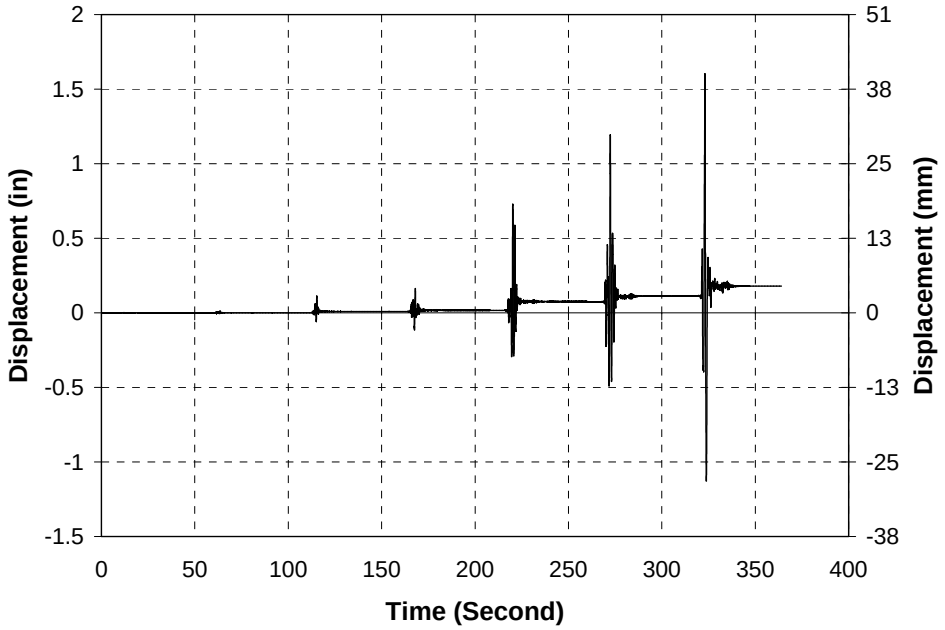


Fig. 3-28. History of Segment Separations at North Side of the SC-2

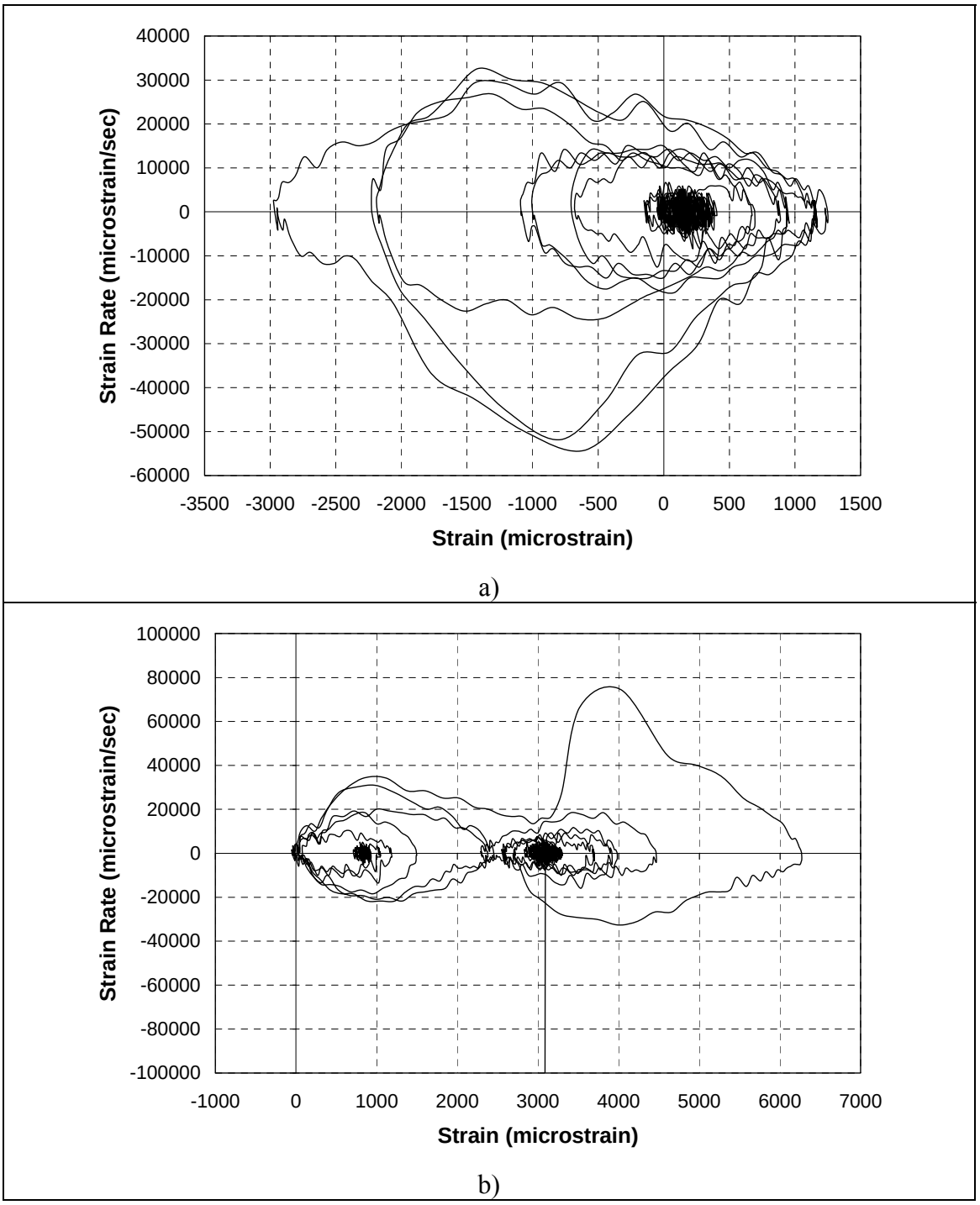


Fig. 3-29. Strain Rate vs. Strain in SC-2 a) Gauge 18, Run 3 b) Gauge 31, Run 4

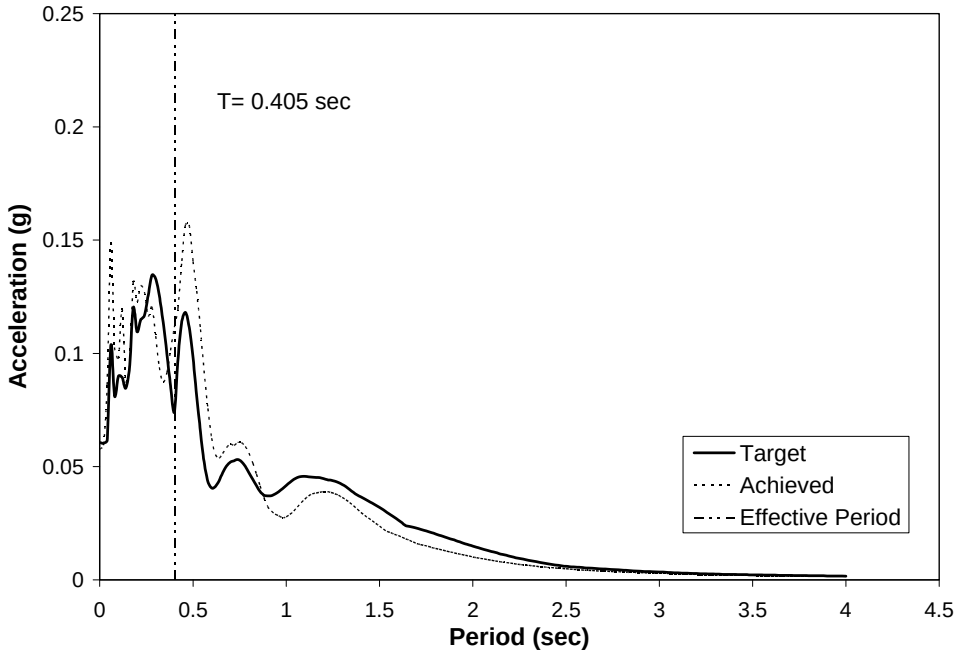


Fig. 3-30. Target vs. Achieved Ground Motion Spectra, Run-1 in SC-2

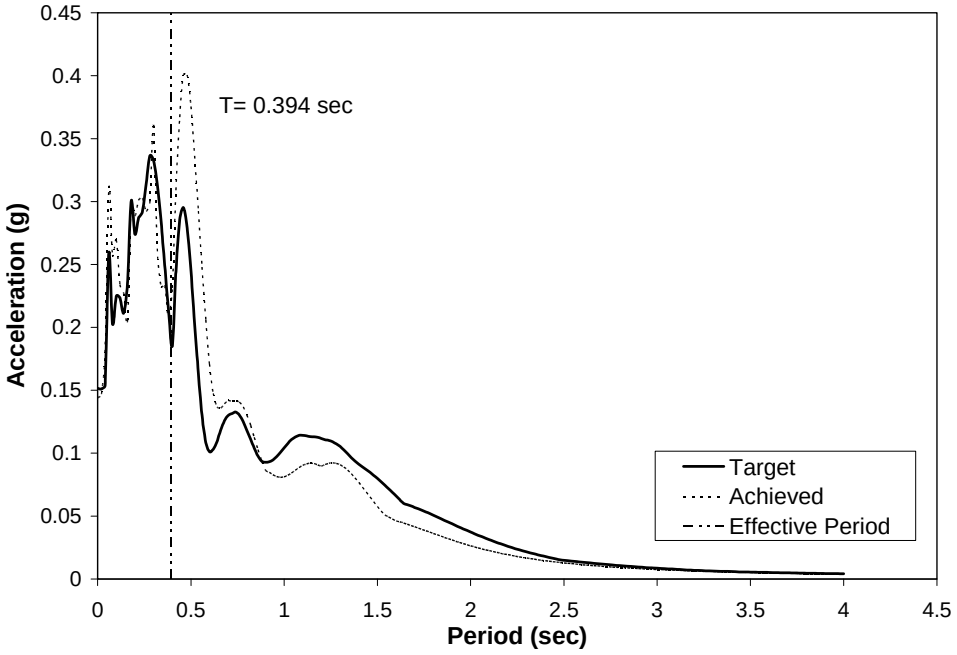


Fig. 3-31. Target vs. Achieved Ground Motion Spectra, Run-2 in SC-2

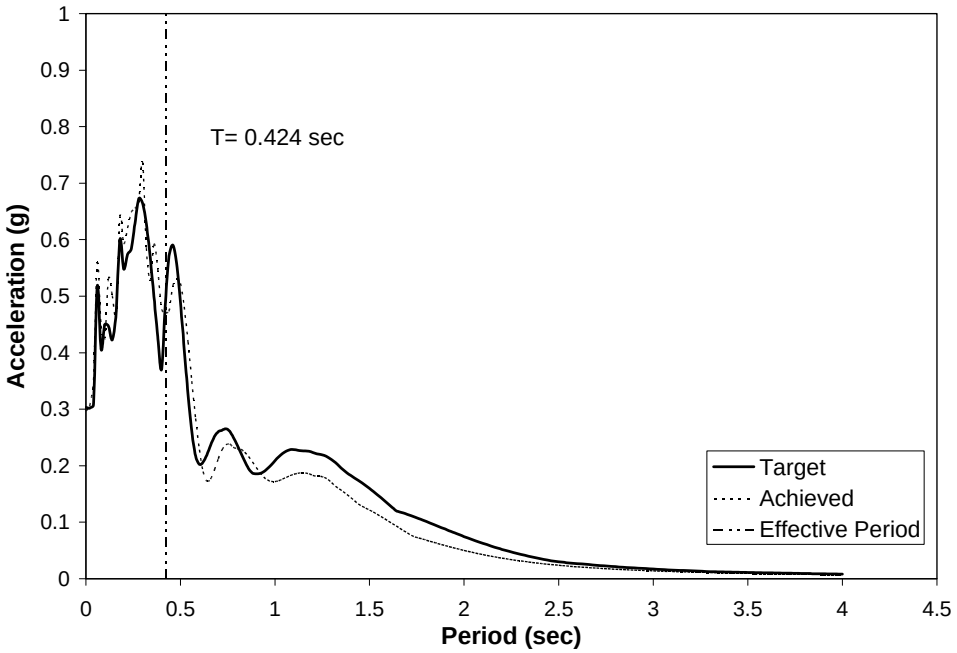


Fig. 3-32. Target vs. Achieved Ground Motion Spectra, Run-3 in SC-2

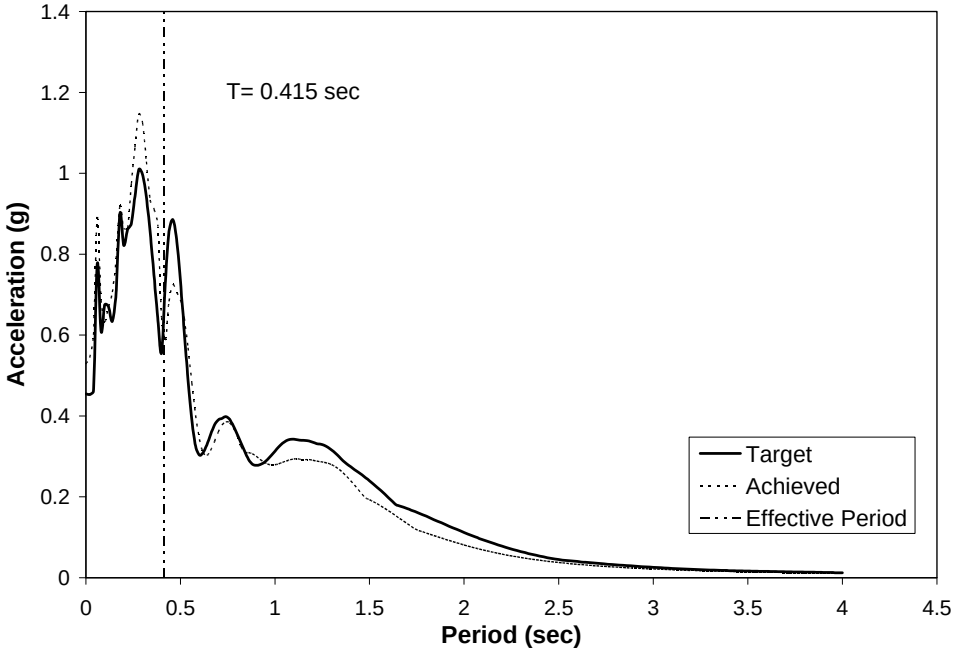


Fig. 3-33. Target vs. Achieved Ground Motion Spectra, Run-4 in SC-2

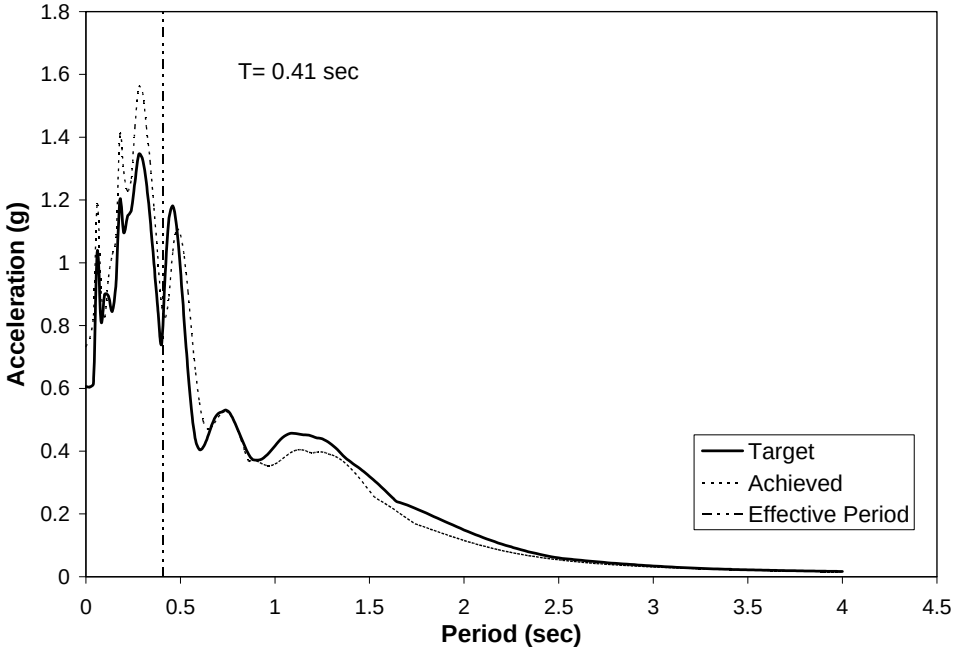


Fig. 3-34. Target vs. Achieved Ground Motion Spectra, Run-5 in SC-2

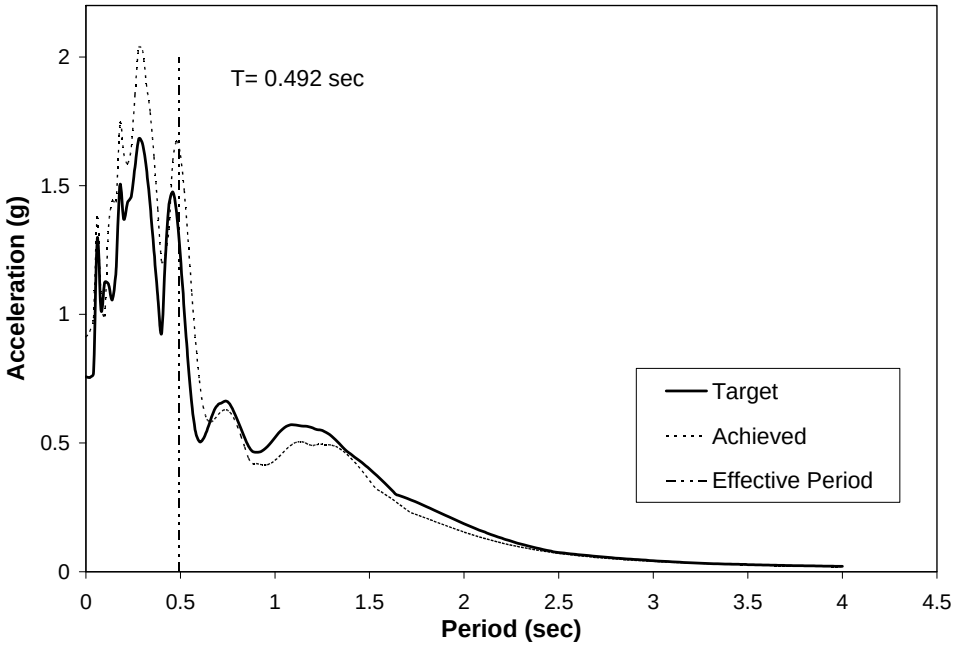


Fig. 3-35. Target vs. Achieved Ground Motion Spectra, Run-6 in SC-2

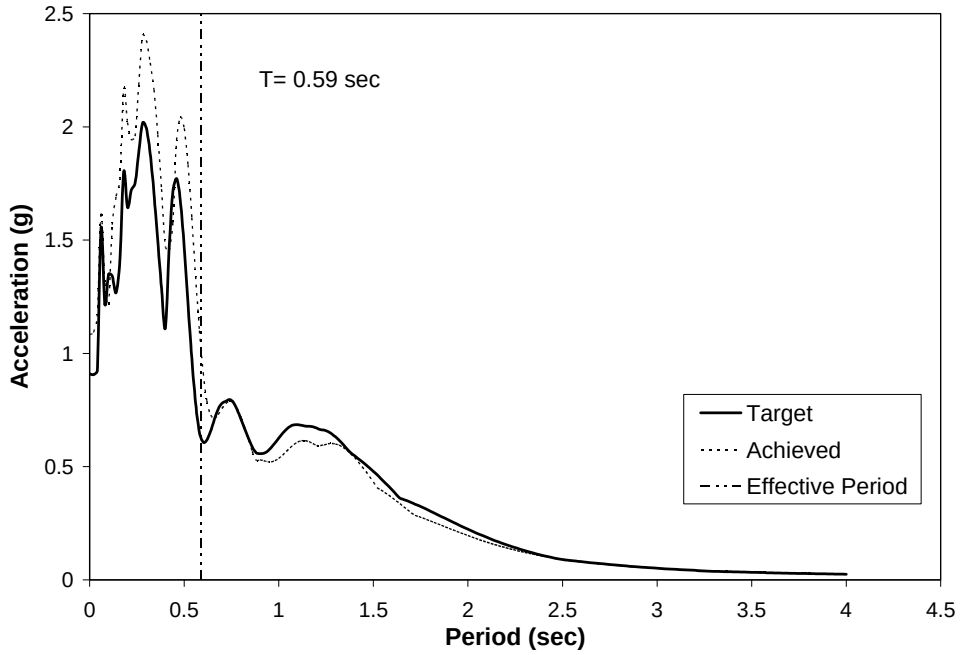
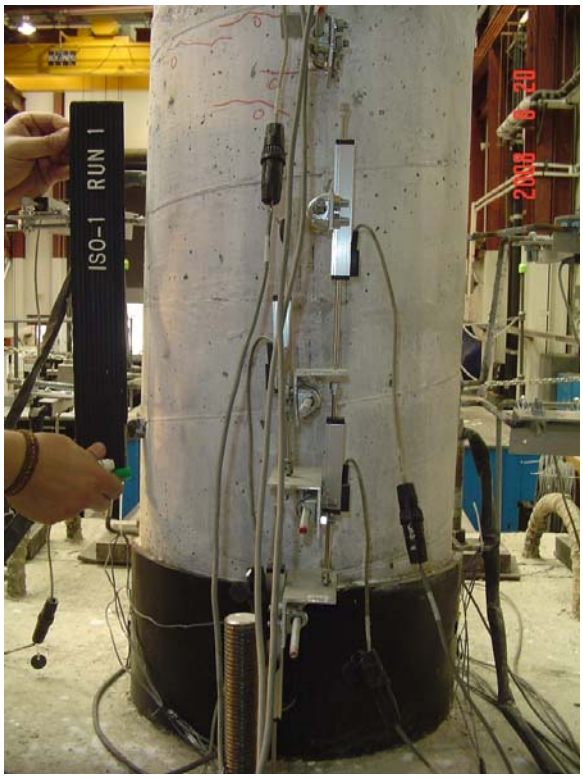
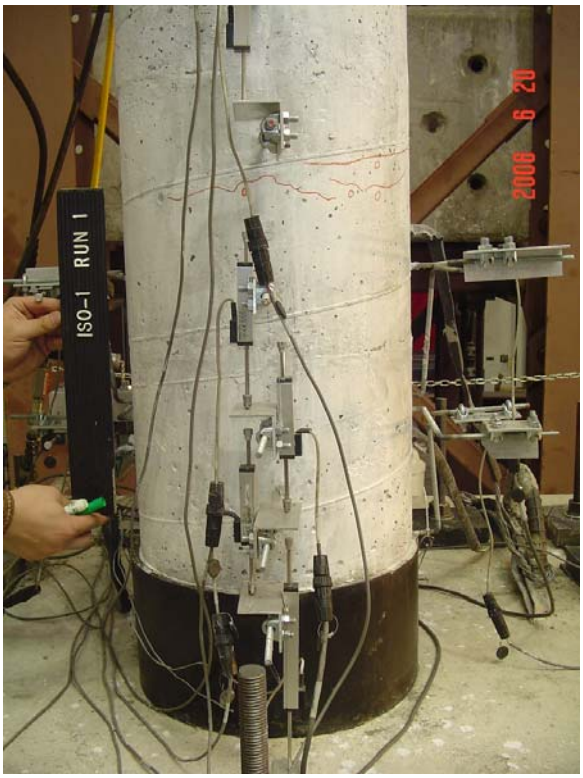


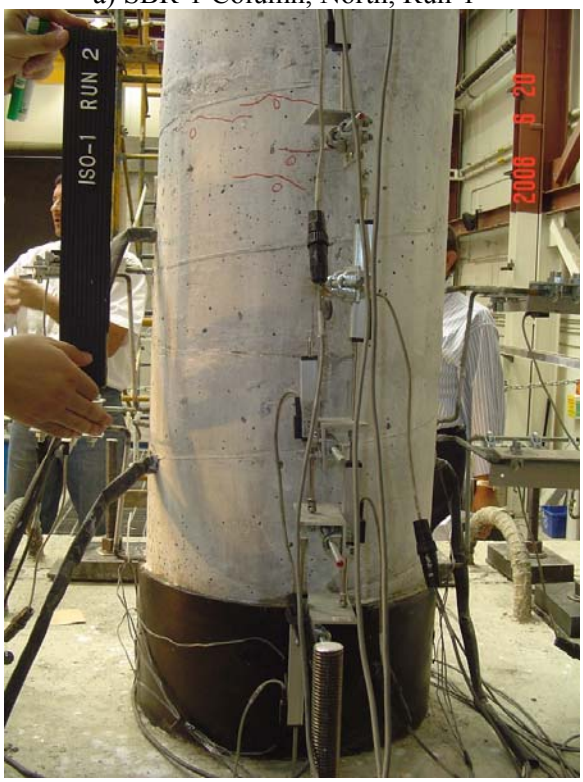
Fig. 3-36. Target vs. Achieved Ground Motion Spectra, Run-7 in SC-2



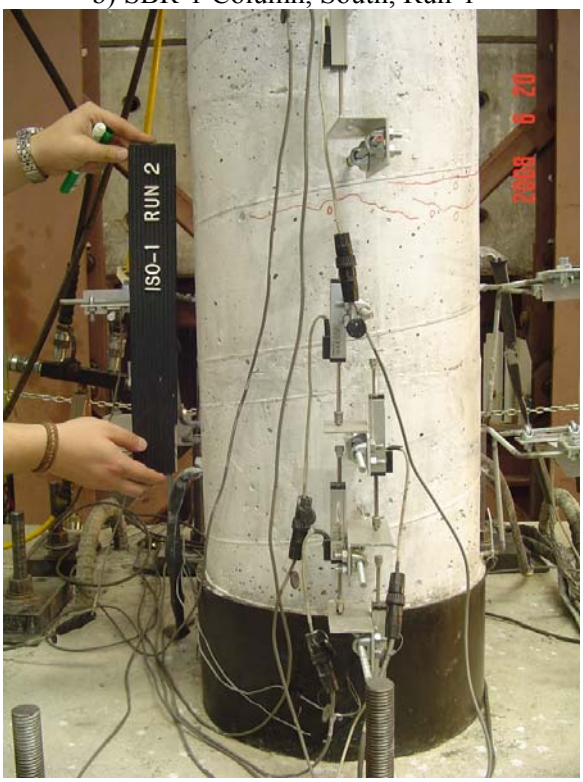
a) SBR-1 Column, North, Run-1



b) SBR-1 Column, South, Run-1

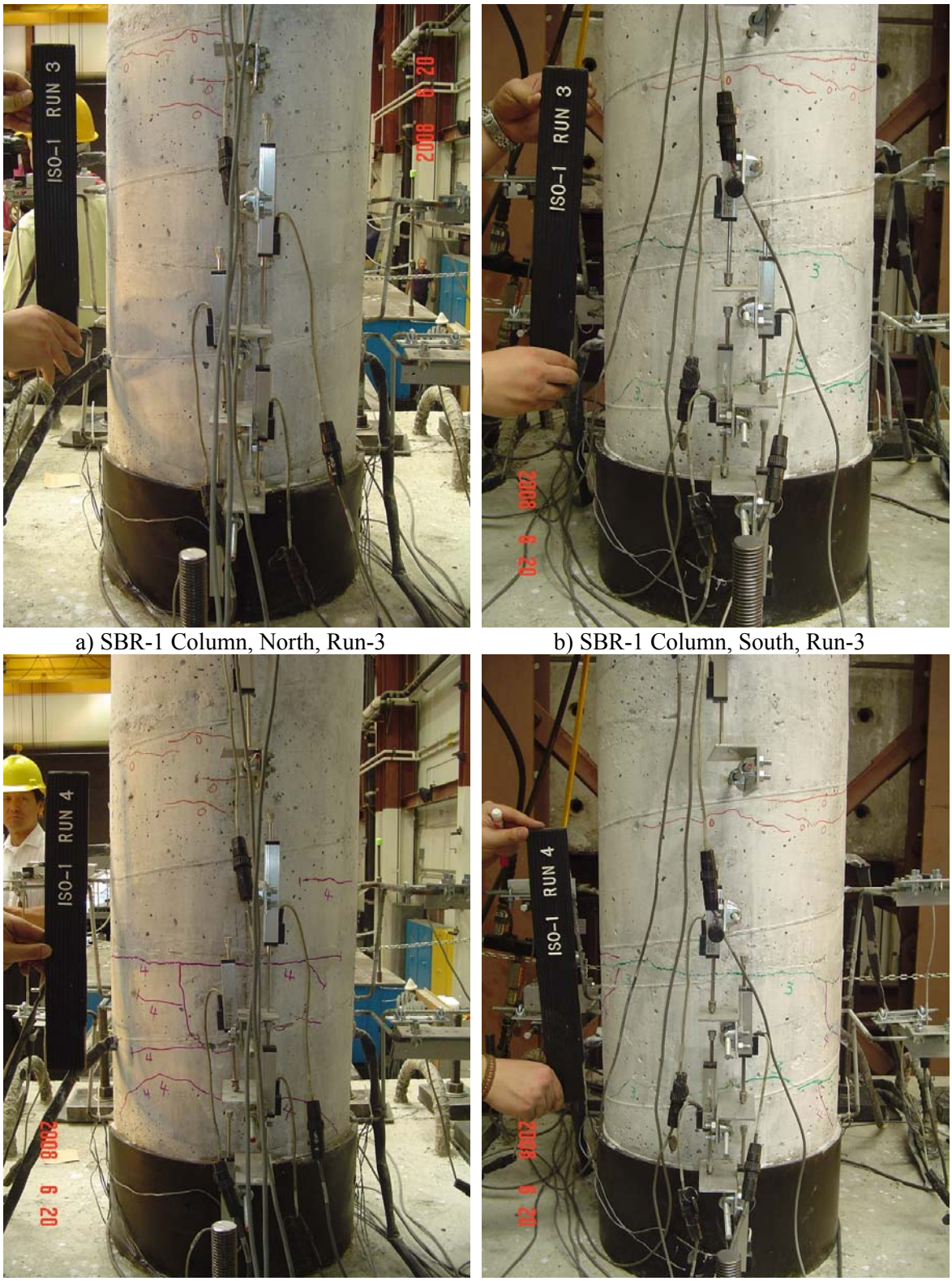


c) SBR-1 Column, North, Run-2



d) SBR-1 Column, South, Run-2

Fig. 3-37. Damage Progression Photographs for SBR-1 Column, Bottom, Run 1 and 2



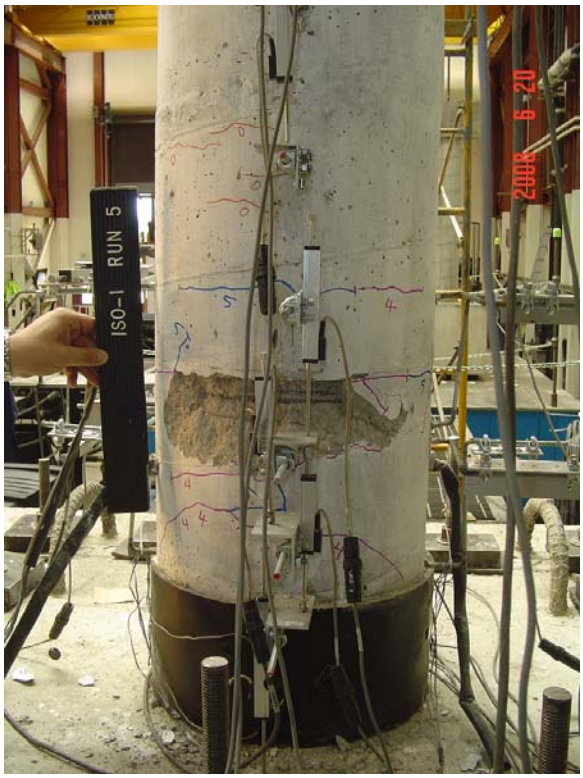
a) SBR-1 Column, North, Run-3

b) SBR-1 Column, South, Run-3

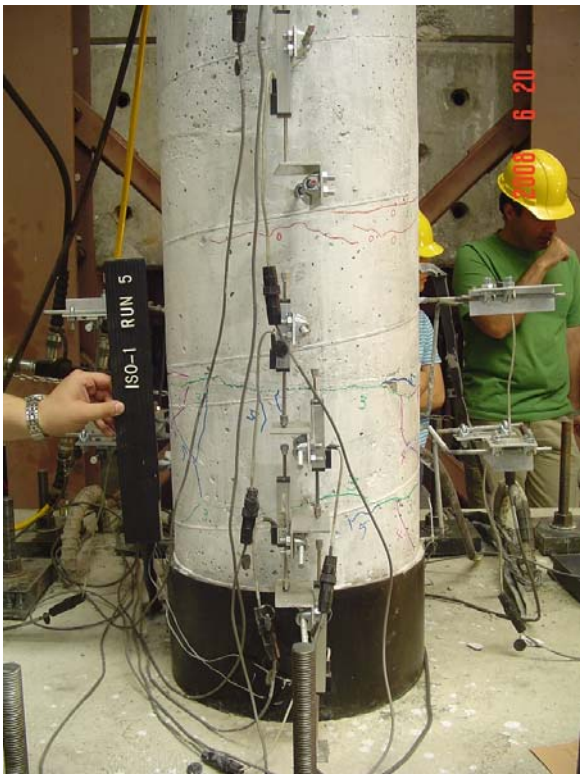
c) SBR-1 Column, North, Run-4

d) SBR-1 Column, South, Run-4

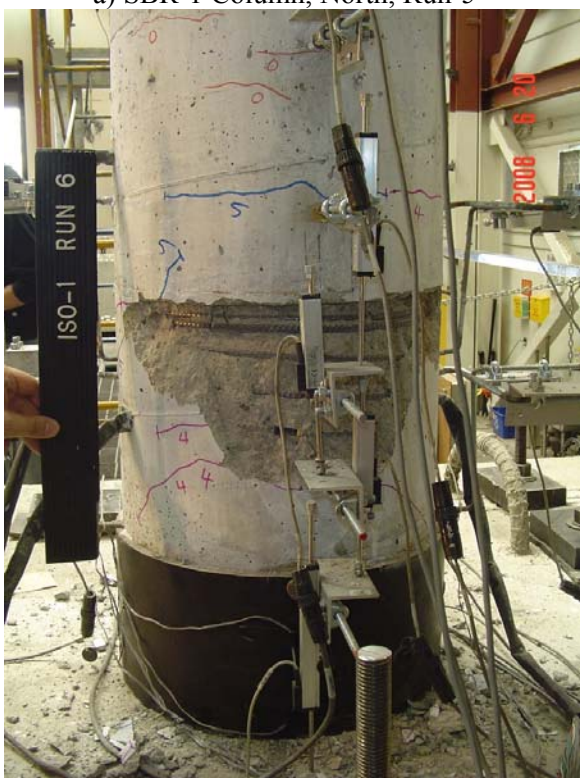
Fig. 3-38. Damage Progression Photographs for SBR-1 Column, Bottom, Run 3 and 4



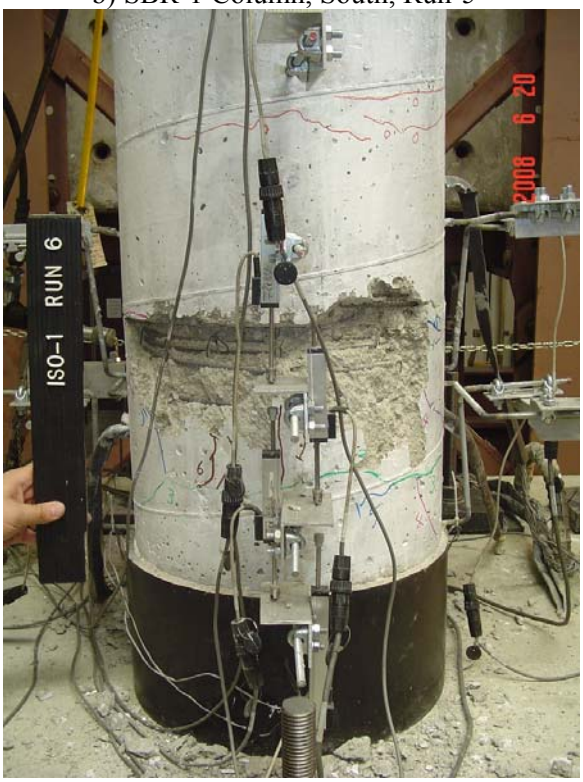
a) SBR-1 Column, North, Run-5



b) SBR-1 Column, South, Run-5

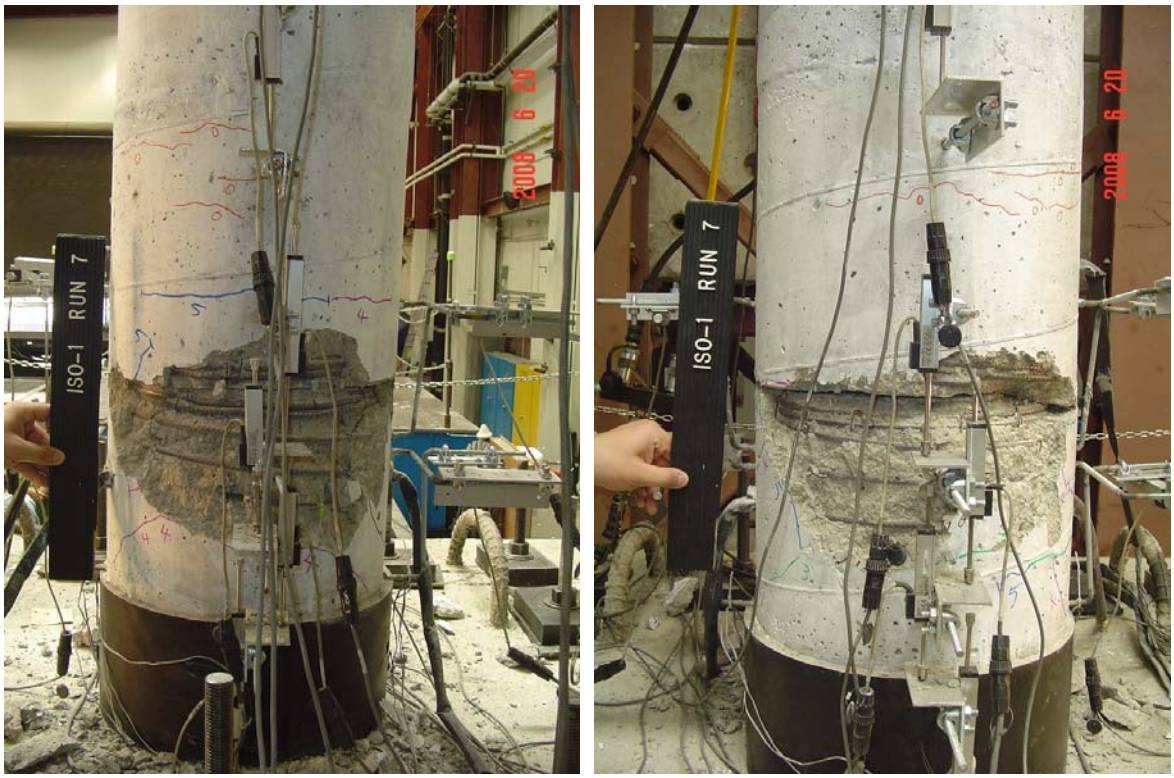


c) SBR-1 Column, North, Run-6



d) SBR-1 Column, South, Run-6

Fig. 3-39. Damage Progression Photographs for SBR-1 Column, Bottom, Run 5 and 6



a) SC-2 Column, North, Run-7 b) SC-2 Column, South, Run-7

Fig. 3-40. Damage Progression Photographs for SC-2 Column, Bottom, Run 7

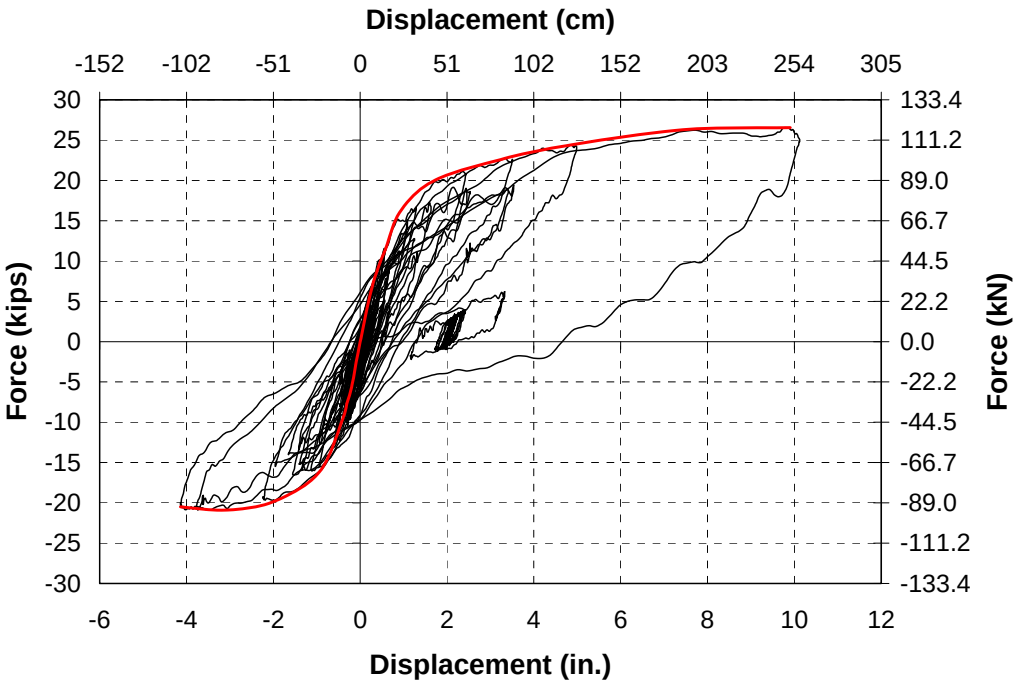


Fig. 3-41. Accumulated Force-Displacement Hysteresis Curve for SBR-1

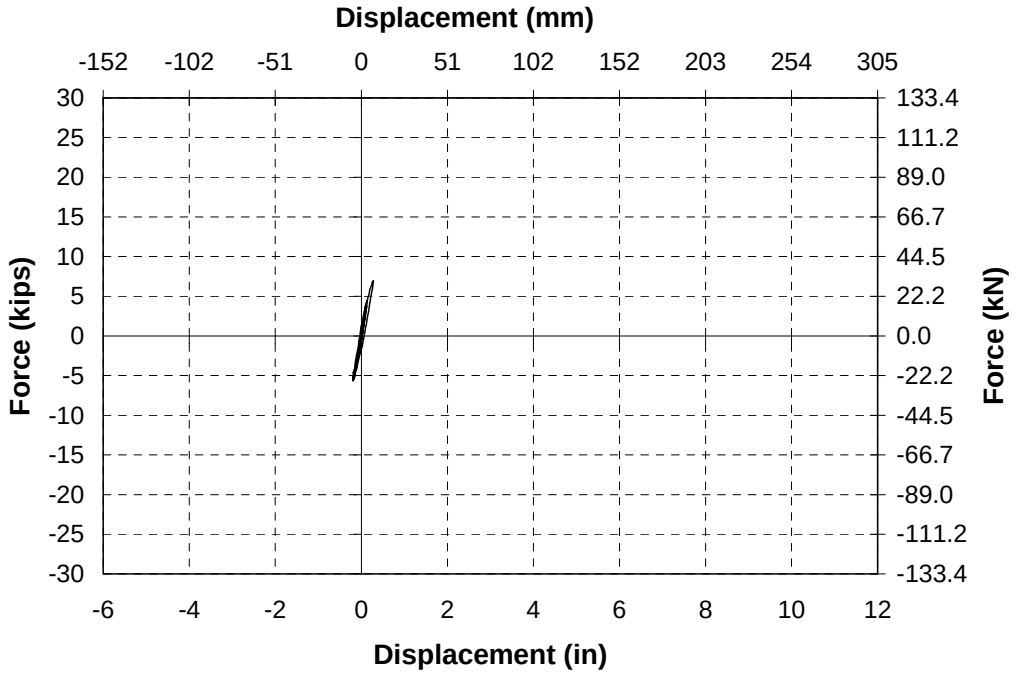


Fig. 3-42. Force-Displacement Hysteresis Curve for Run 1 in SBR-1

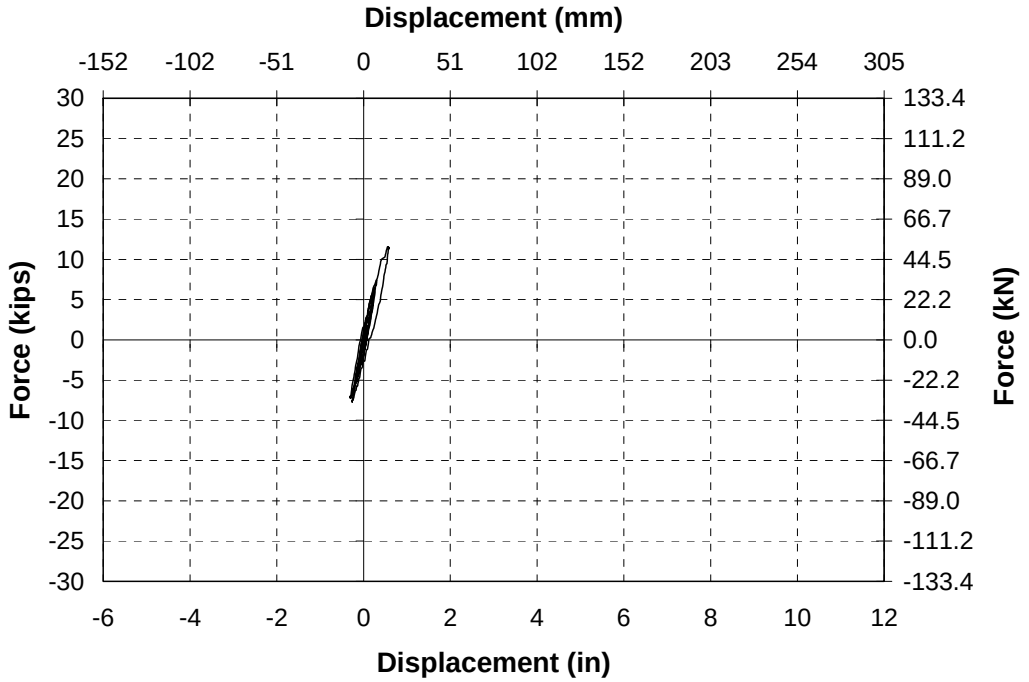


Fig. 3-43. Force-Displacement Hysteresis Curve for Run 2 in SBR-1

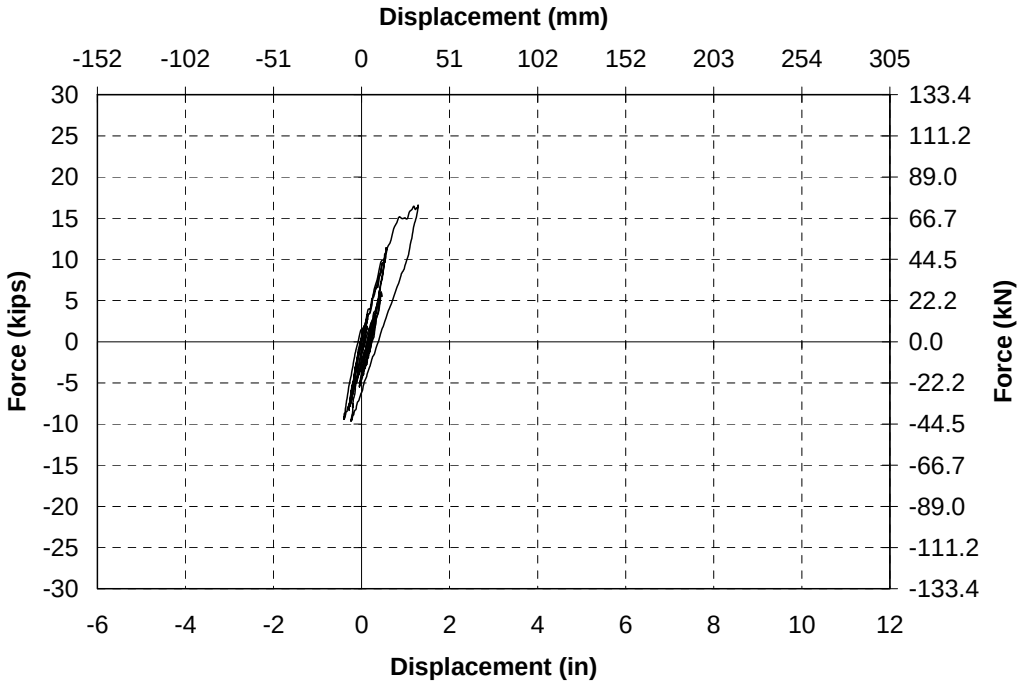


Fig. 3-44. Force-Displacement Hysteresis Curve for Run 3 in SBR-1

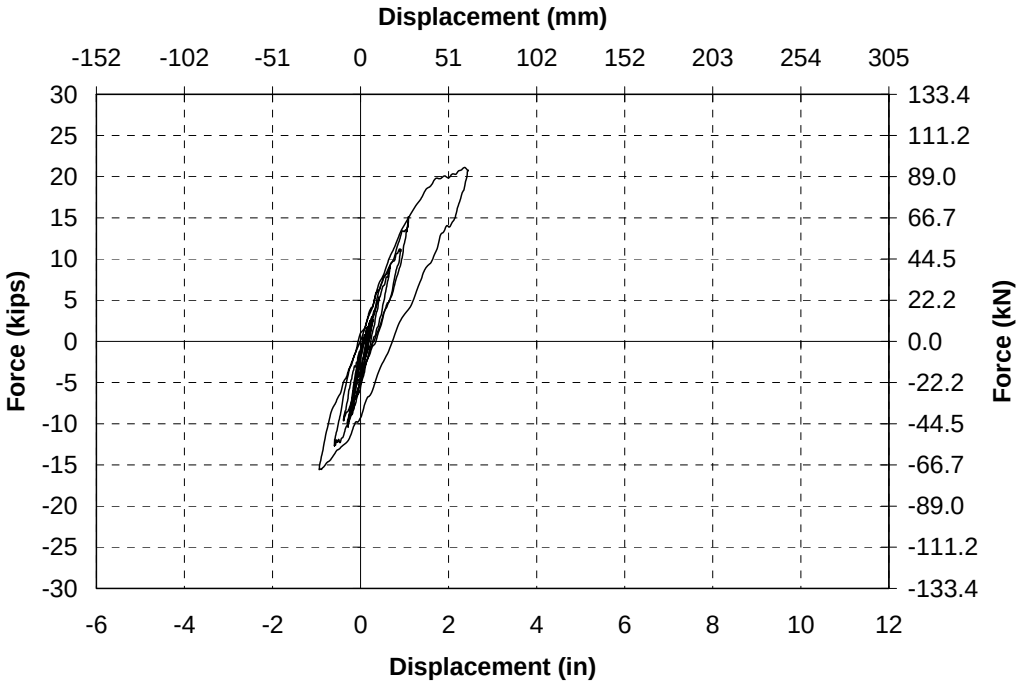


Fig. 3-45. Force-Displacement Hysteresis Curve for Run 4 in SBR-1

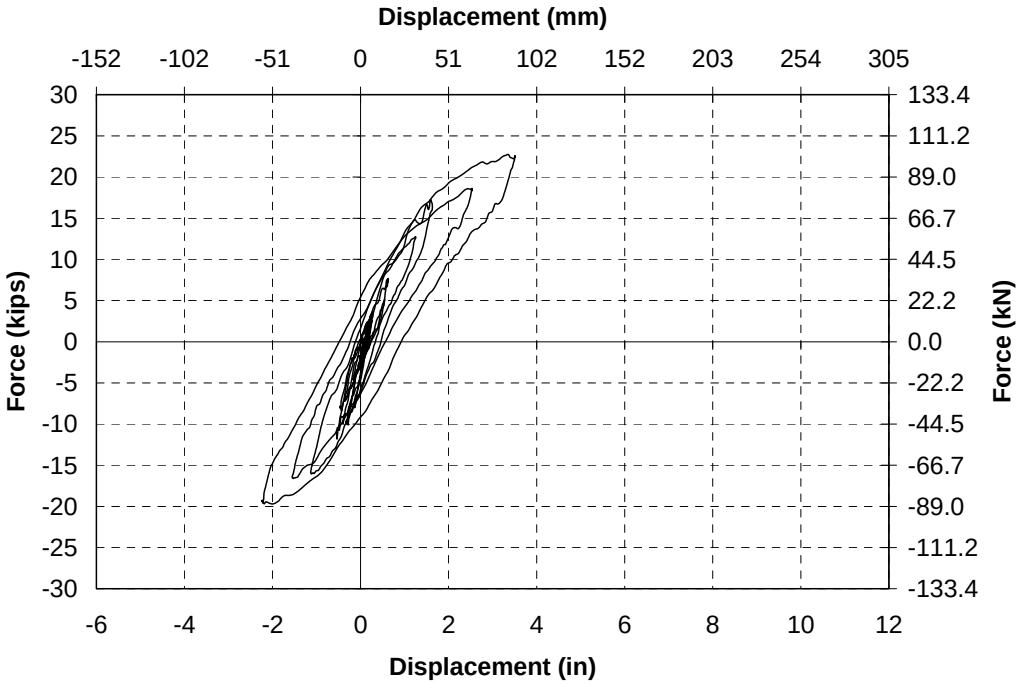


Fig. 3-46. Force-Displacement Hysteresis Curve for Run 5 in SBR-1

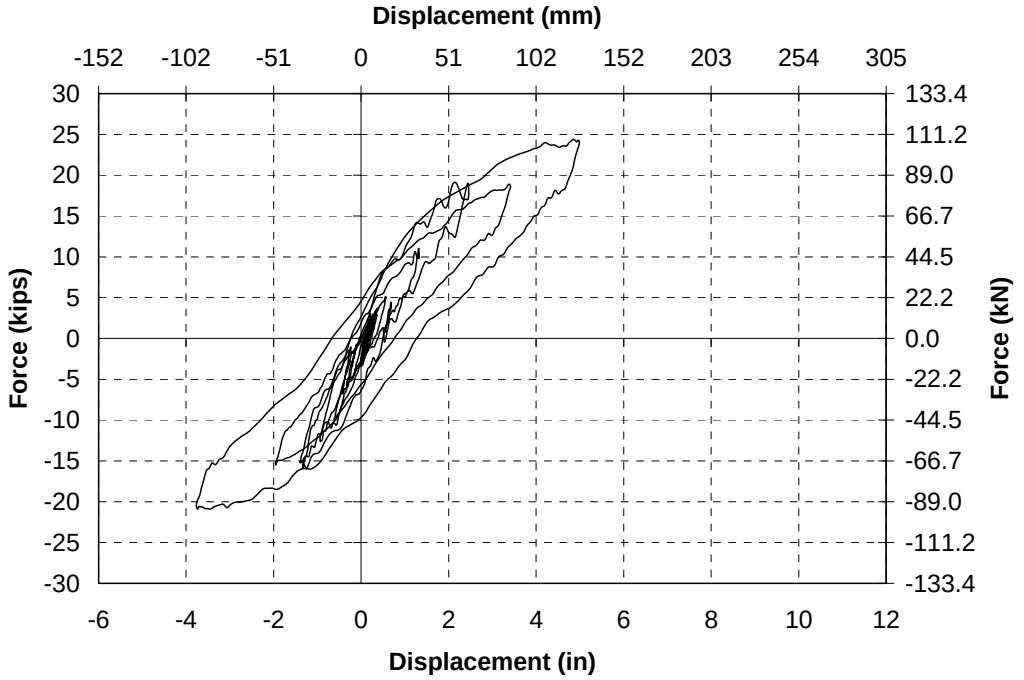


Fig. 3-47. Force-Displacement Hysteresis Curve for Run 6 in SBR-1

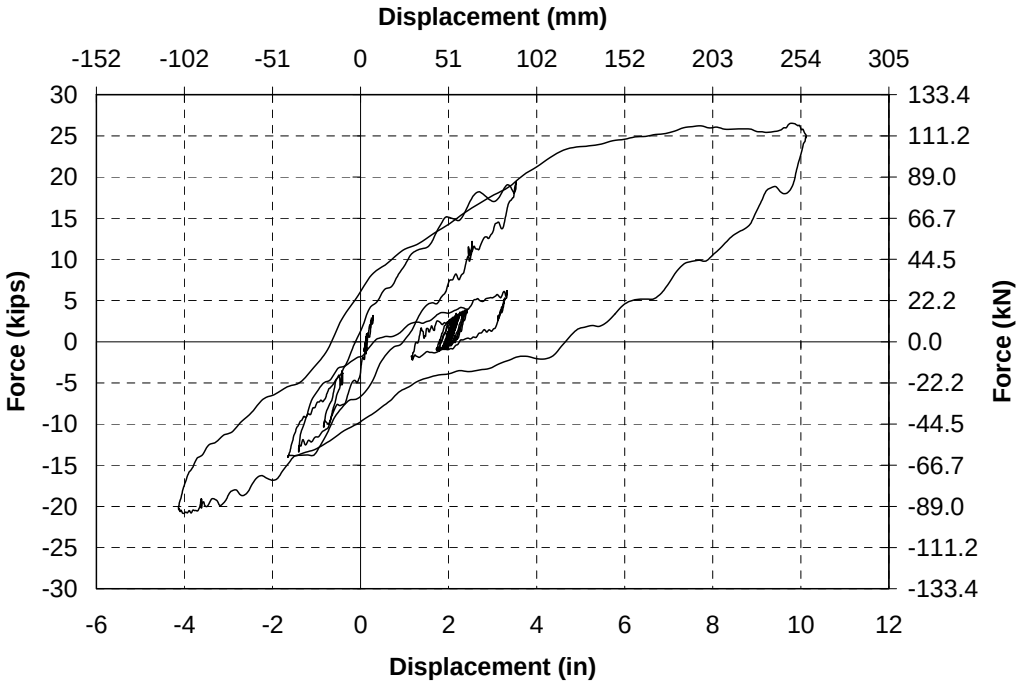


Fig. 3-48. Force-Displacement Hysteresis Curve for Run 7 in SBR-1

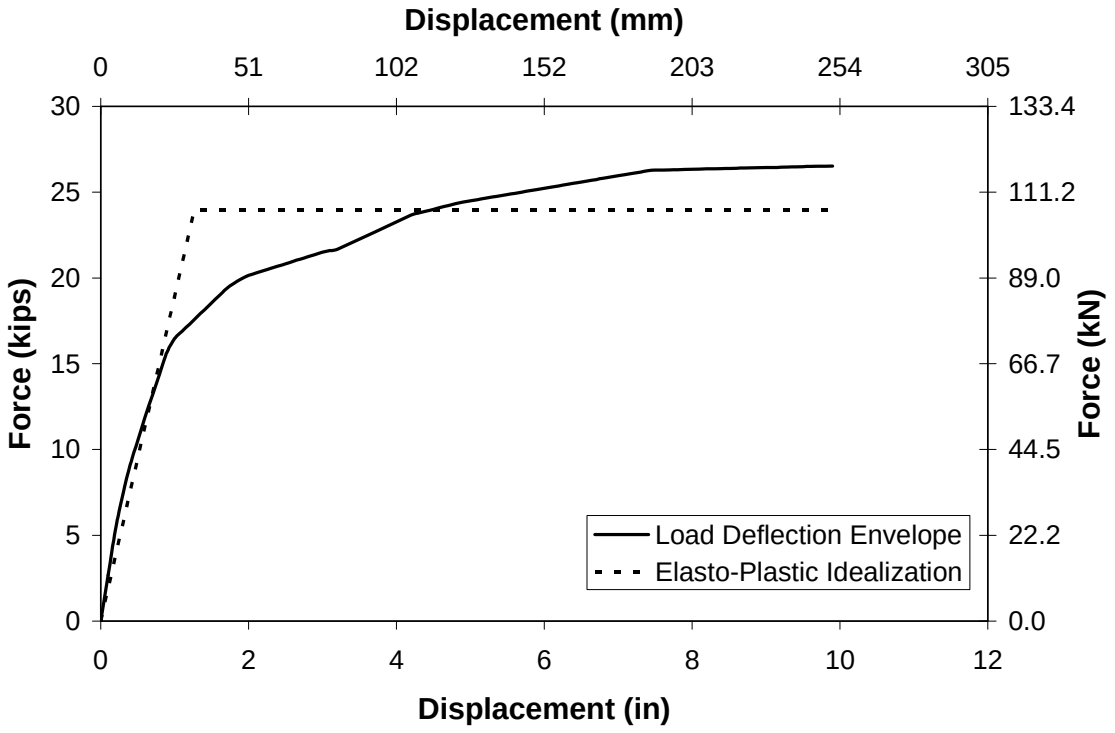


Fig. 3-49. Backbone Curve of SBR-1

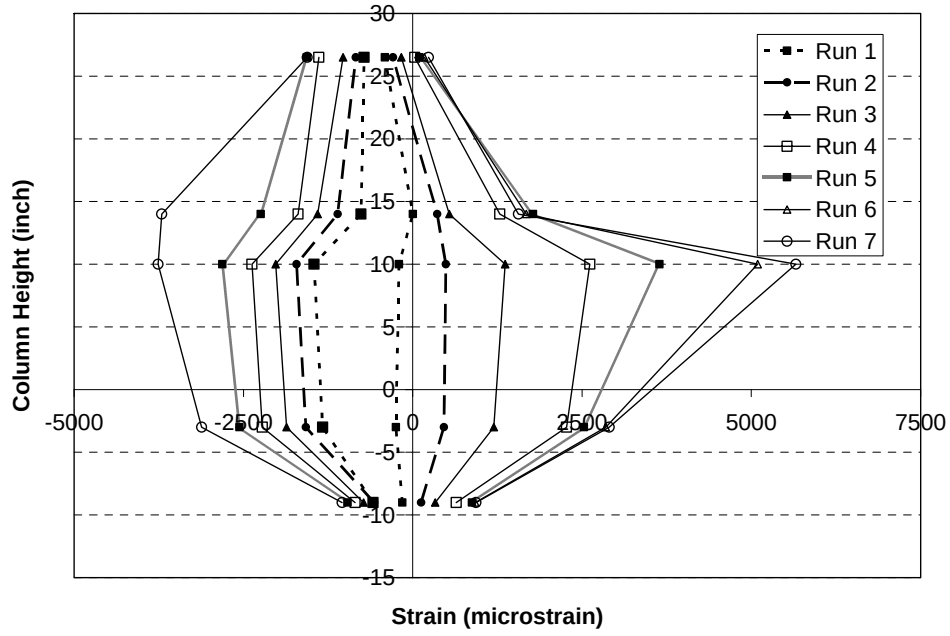


Fig. 3-50. The Max. and Min. Long. Strain Profile of the SBR-1

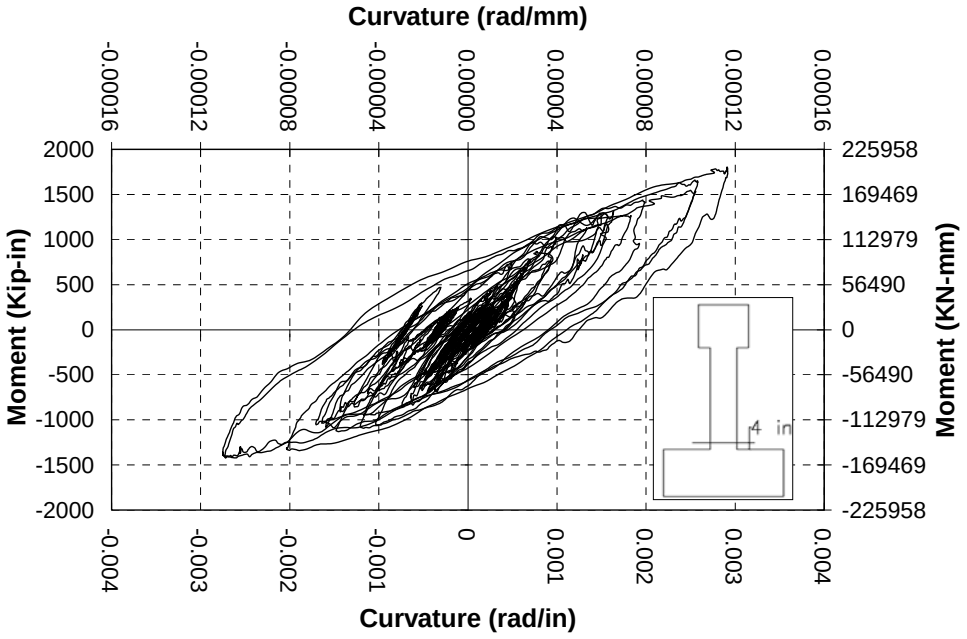


Fig. 3-51. Accumulated Moment Curvature at the First Level in SBR-1

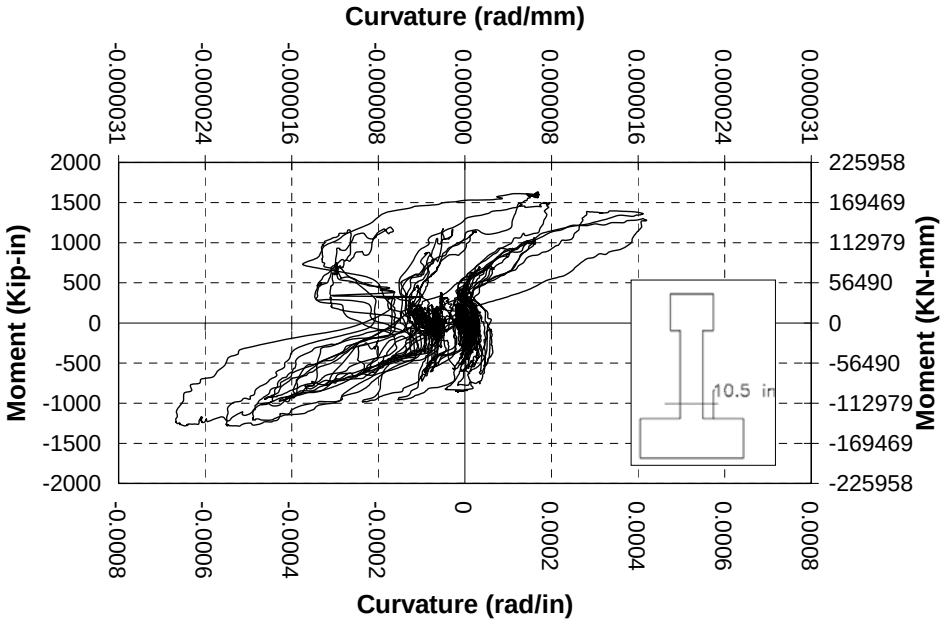


Fig. 3-52. Accumulated Moment Curvature at the Second Level in SBR-1

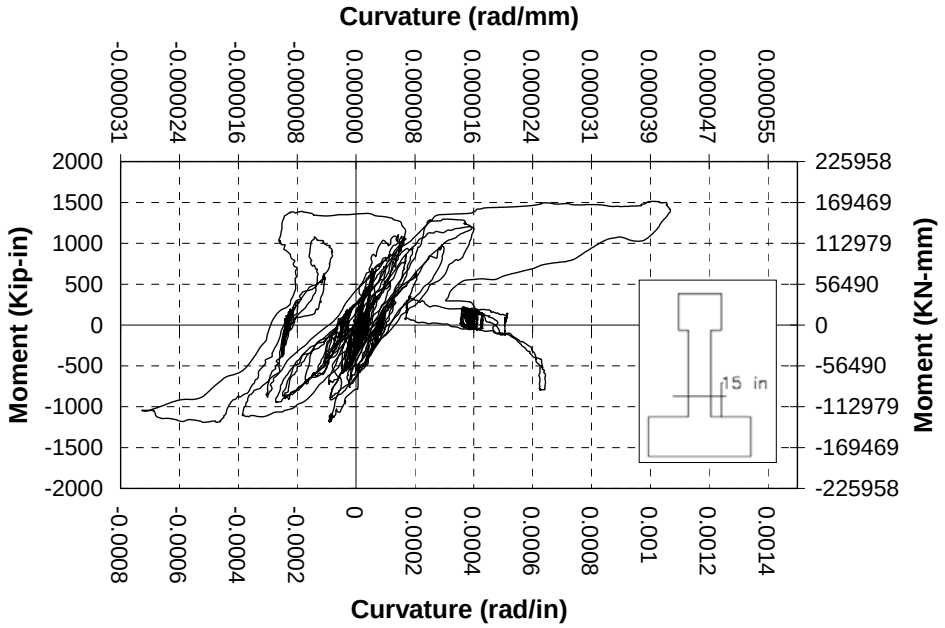


Fig. 3-53. Accumulated Moment Curvature at the Third Level in SBR-1

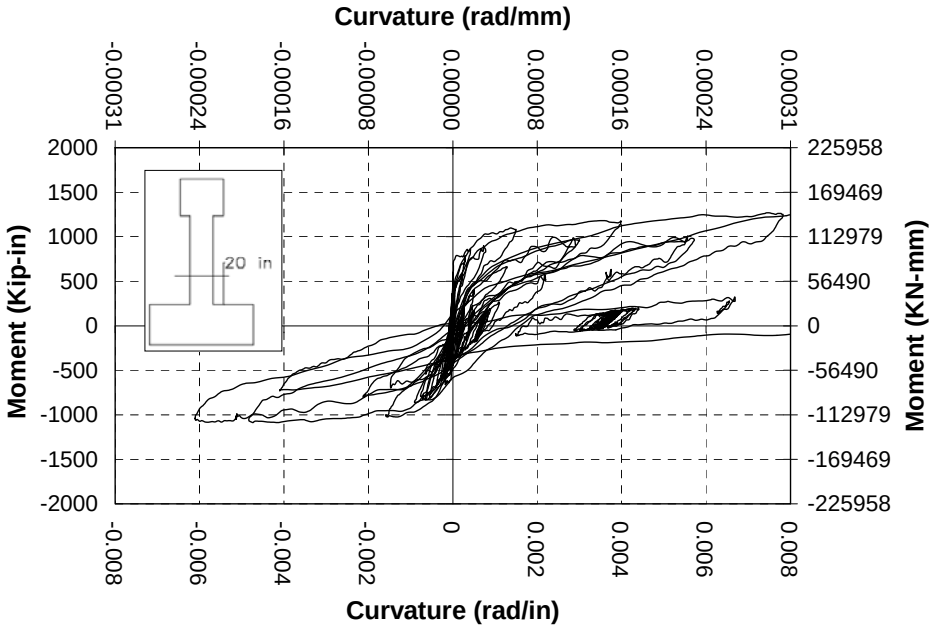


Fig. 3-54. Accumulated Moment Curvature at the Fourth Level in SBR-1

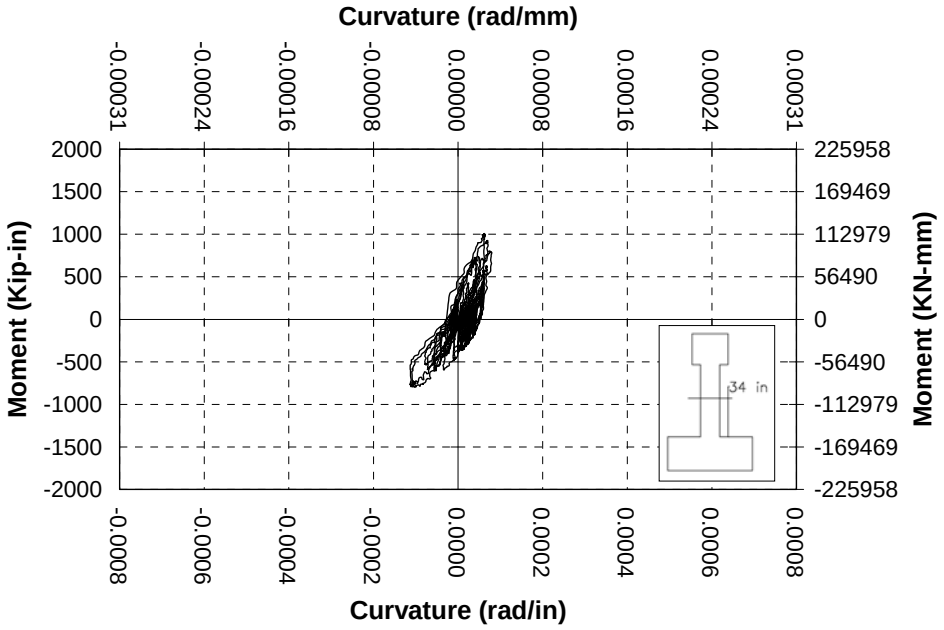


Fig. 3-55. Accumulated Moment Curvature at the Fifth Level in SBR-1

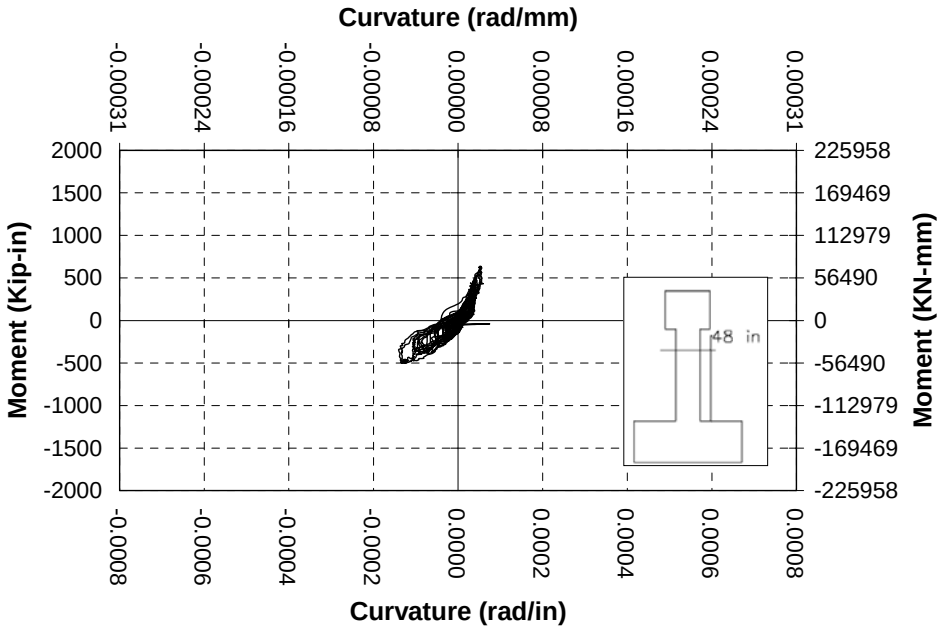


Fig. 3-56. Accumulated Moment Curvature at the Sixth Level in SBR-1

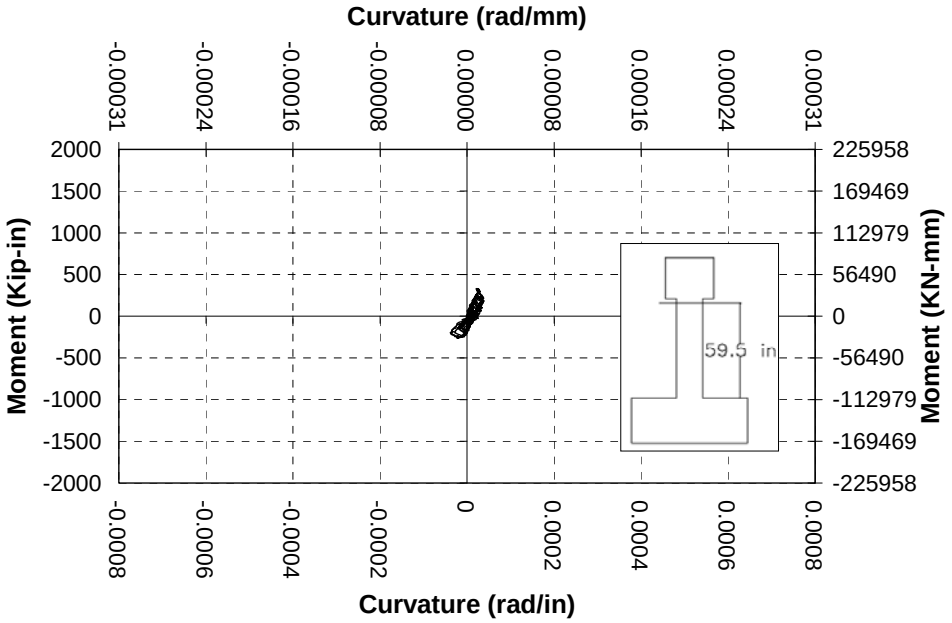


Fig. 3-57. Accumulated Moment Curvature at the Seventh Level in SBR-1

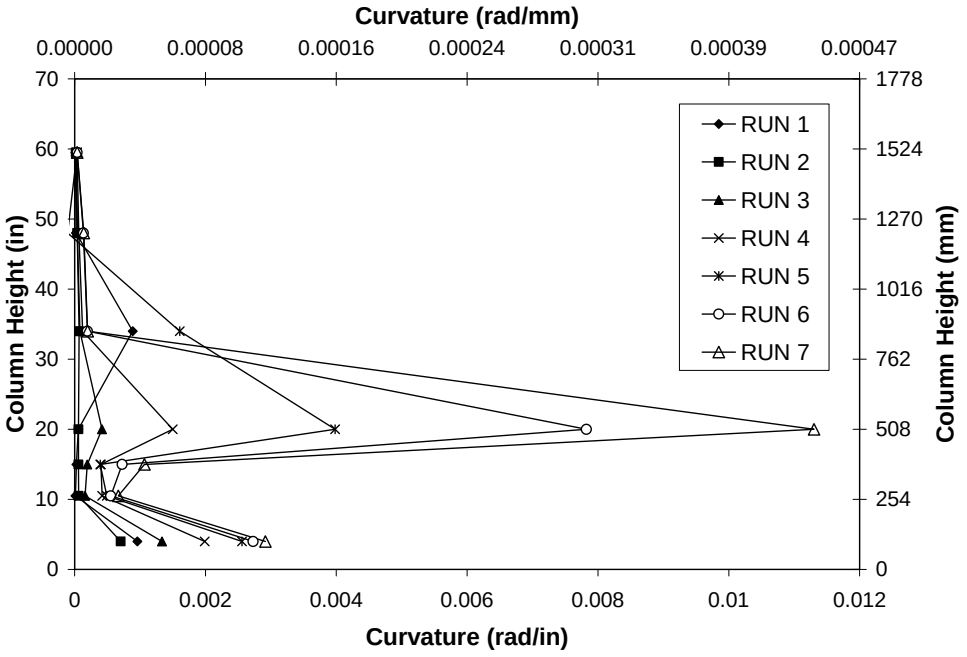


Fig. 3-58. Curvature Profile for SBR-1

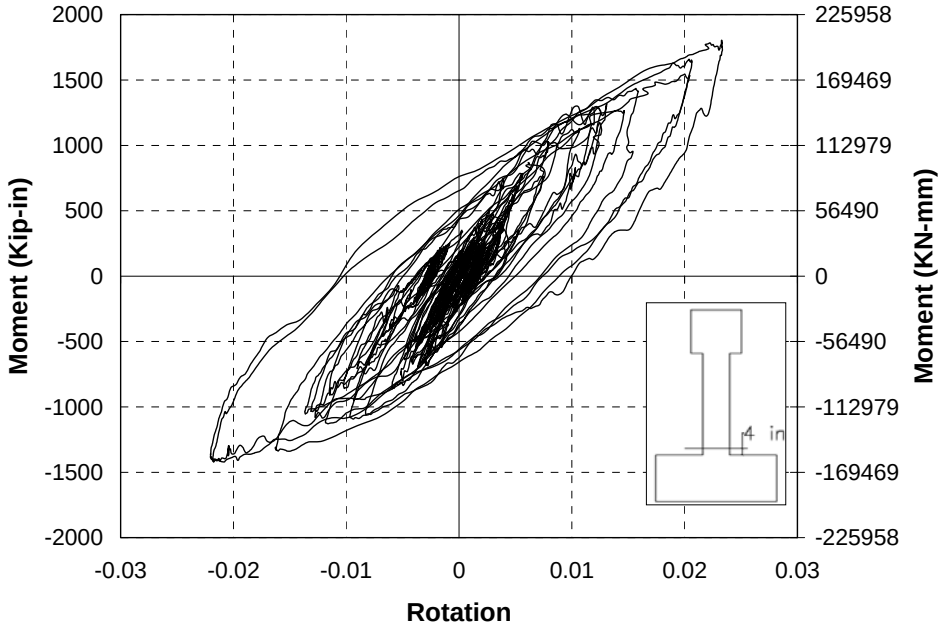


Fig. 3-59. Moment vs. Rotation at Elastomeric Bearing for Column SBR-1

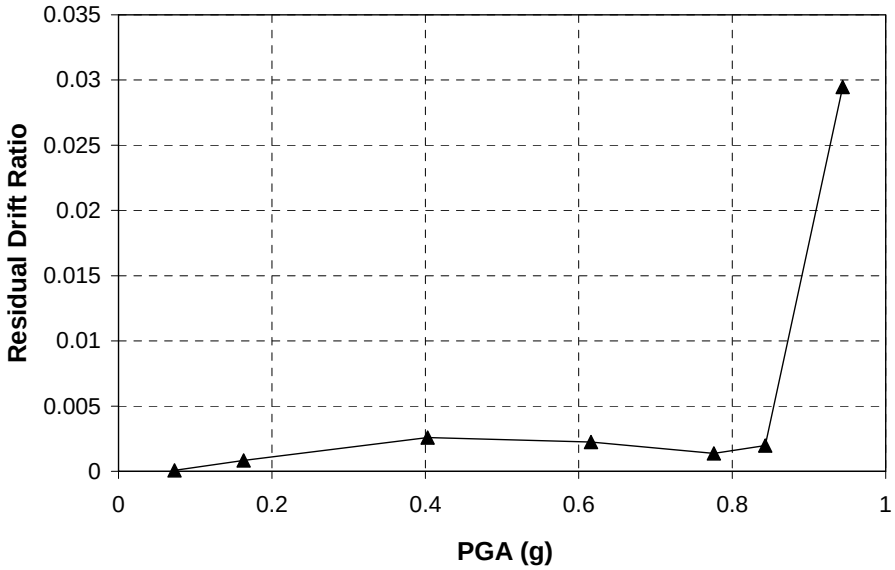


Fig. 3-60. Residual Drift Ratio vs. PGA in SBR-1

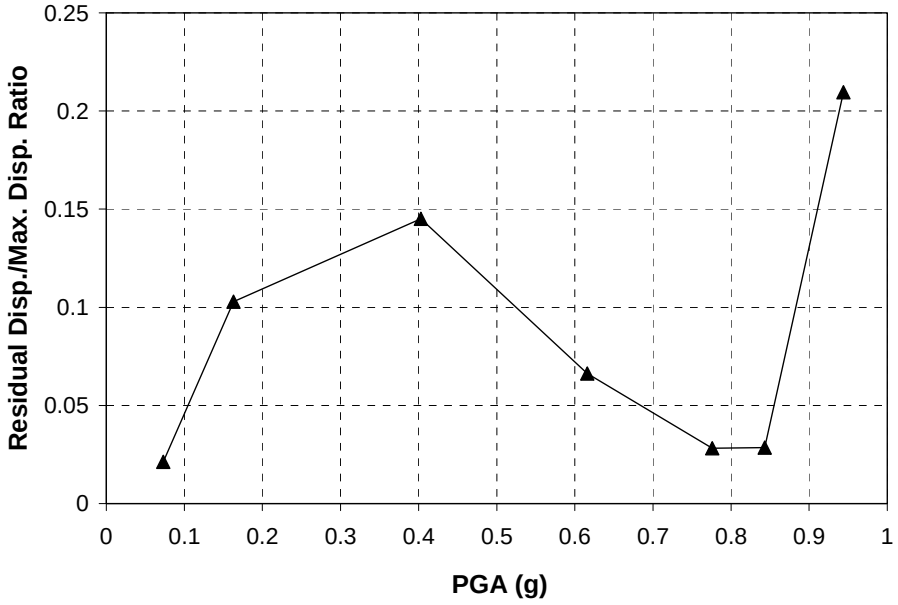


Fig. 3-61. Residual Disp. / Maxi. Disp. vs. PGA in SBR-1

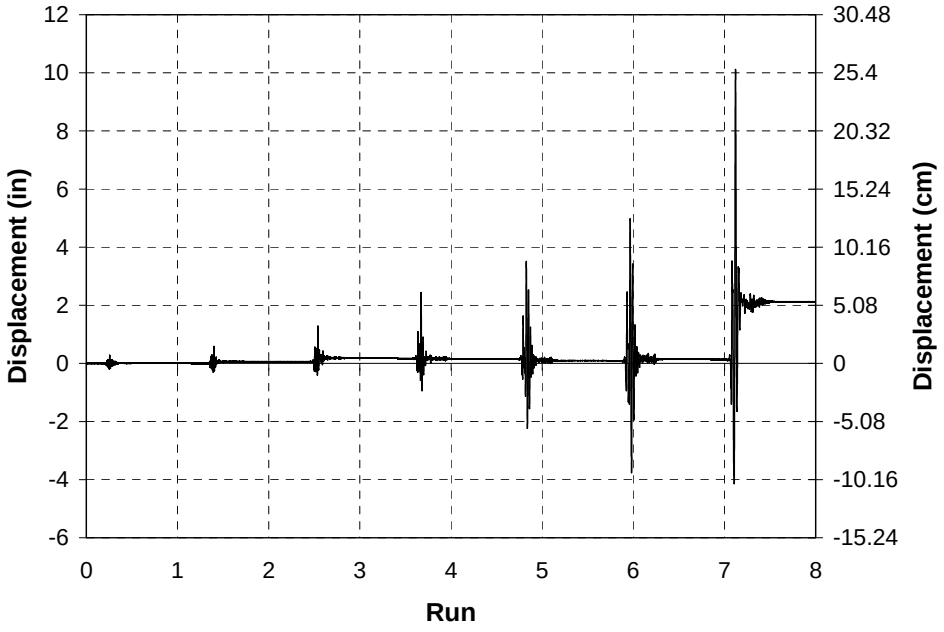


Fig. 3-62. Displacement History in Column SBR-1

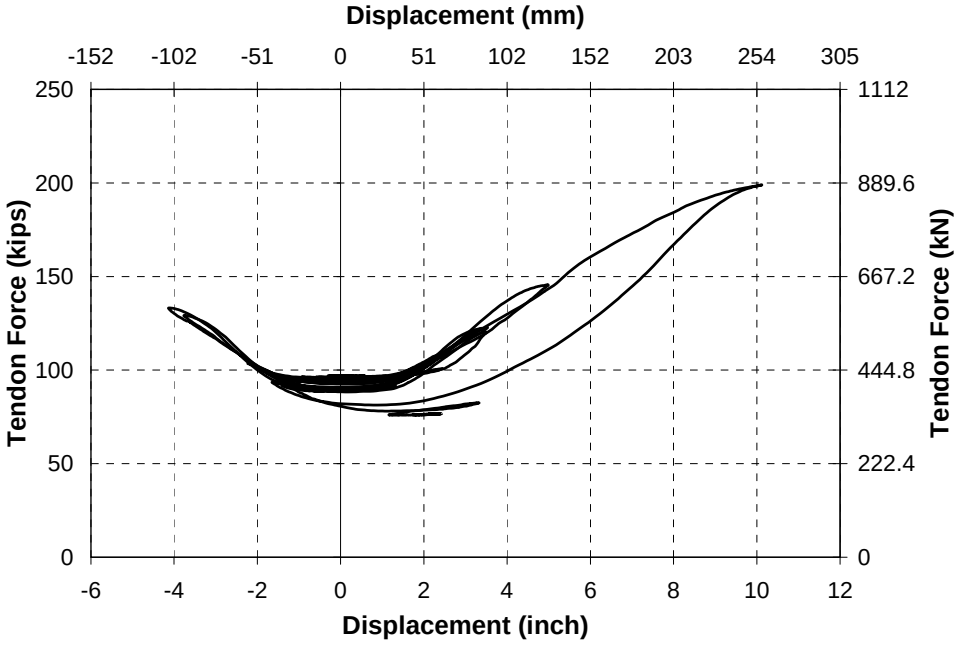


Fig. 3-63. Unbonded PT Rod Force vs. Displacement in SBR-1

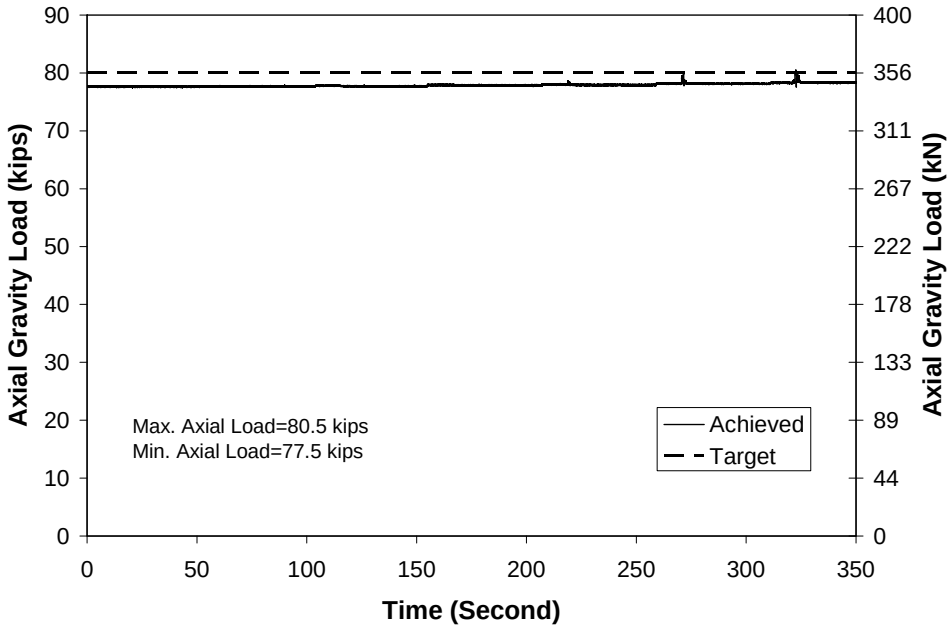


Fig. 3-64. Axial Gravity Load History on SBR-1

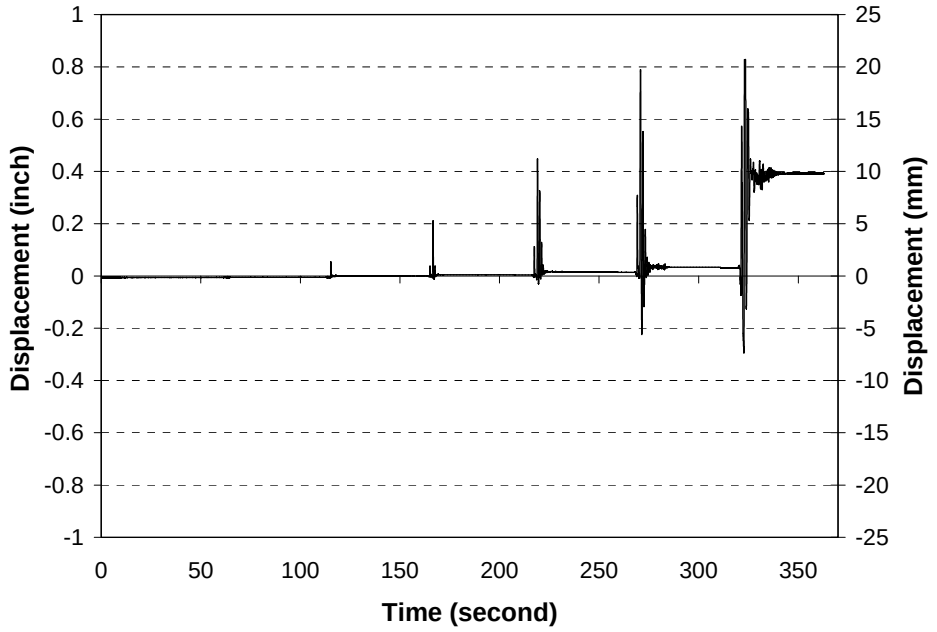


Fig. 3-65. History of Segment Separation at South Side of the SBR-1

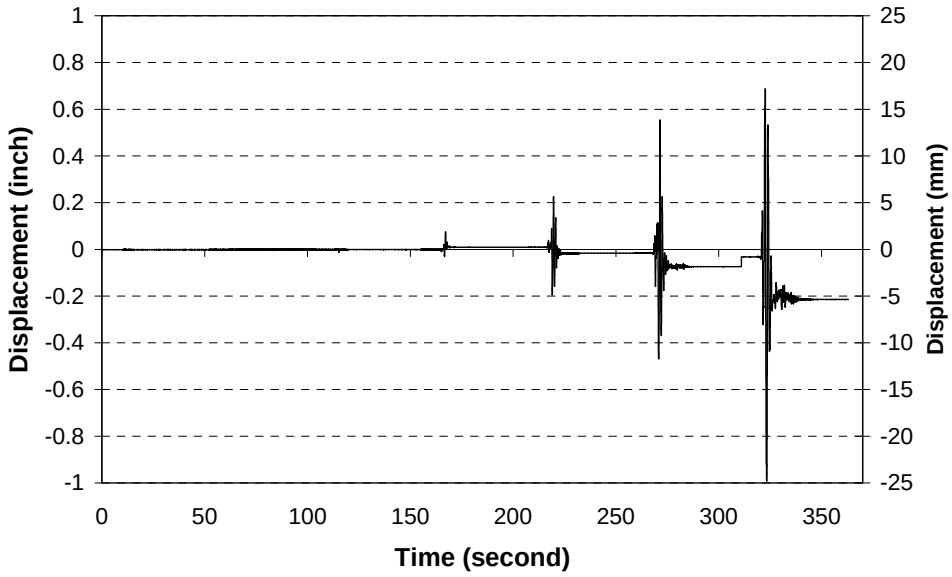
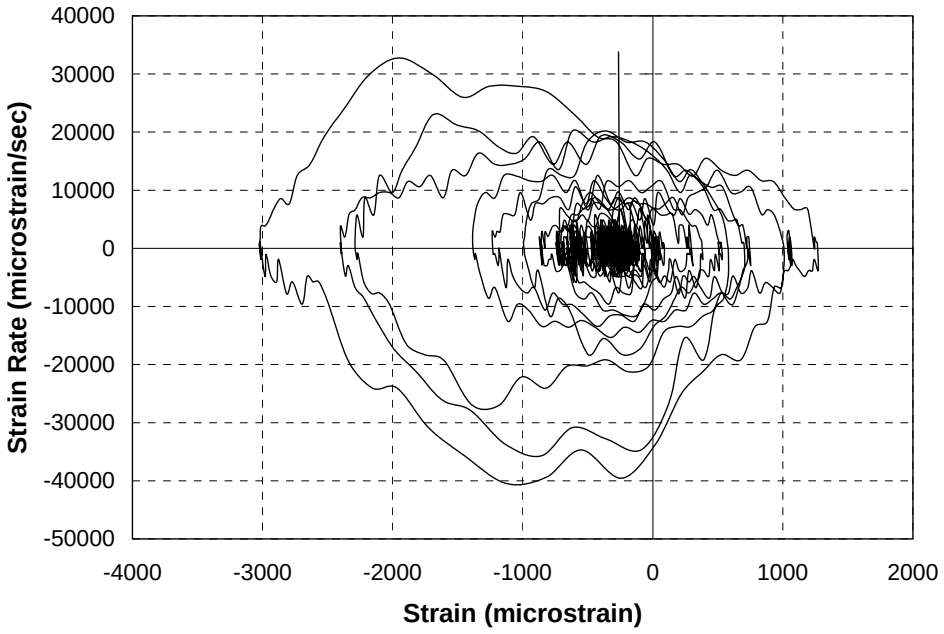
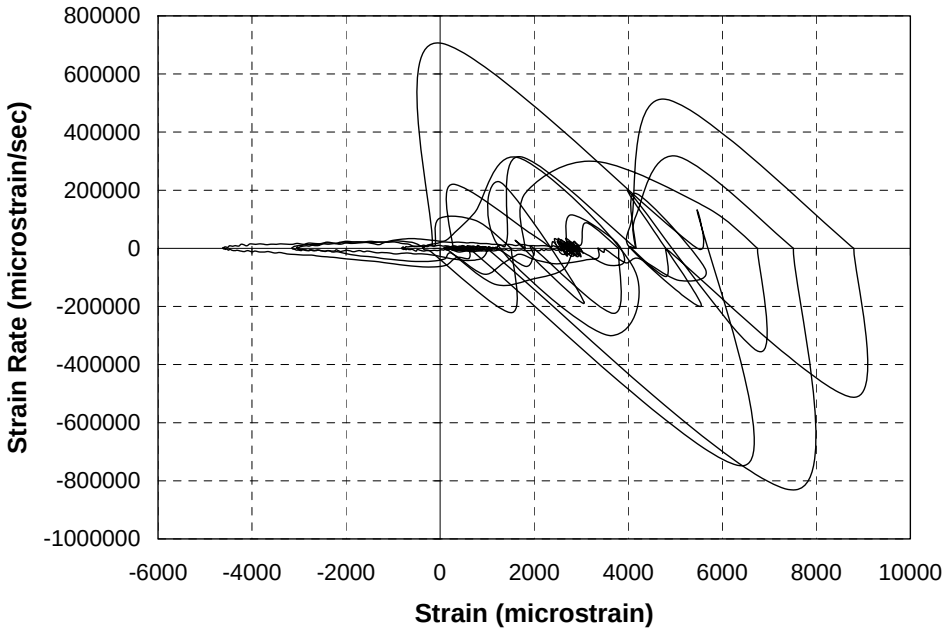


Fig. 3-66. History of Segment Separation at North Side of the SBR-1



a)



b)

Fig. 3-67. Strain Rate vs. Strain in SBR-1 a) Gauge 12, Run 3 b) Gauge 12, Run 6

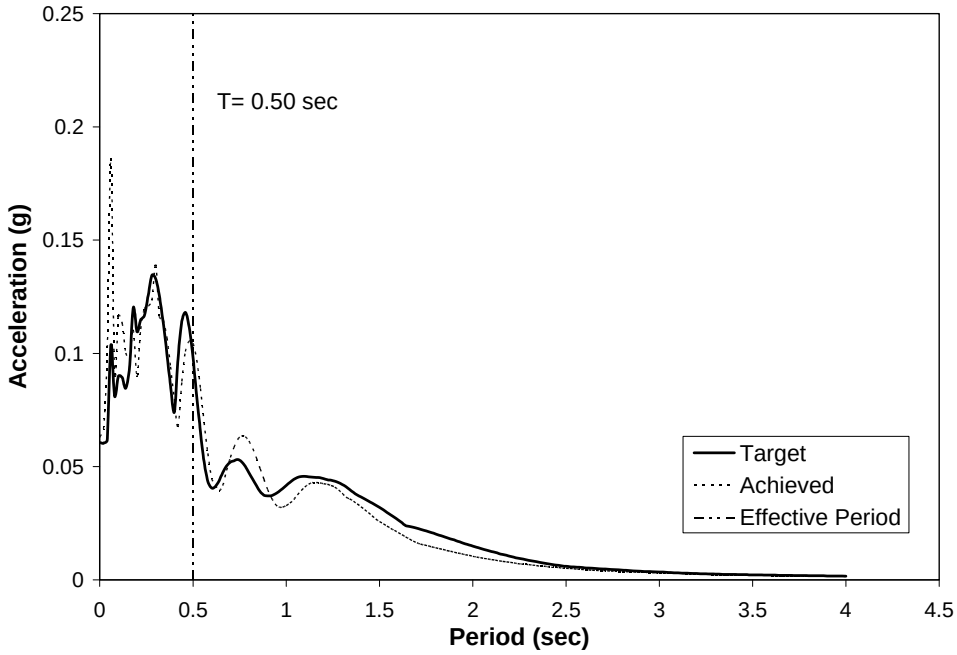


Fig. 3-68. Target vs. Achieved Ground Motion Spectra, Run-1 in SBR-1

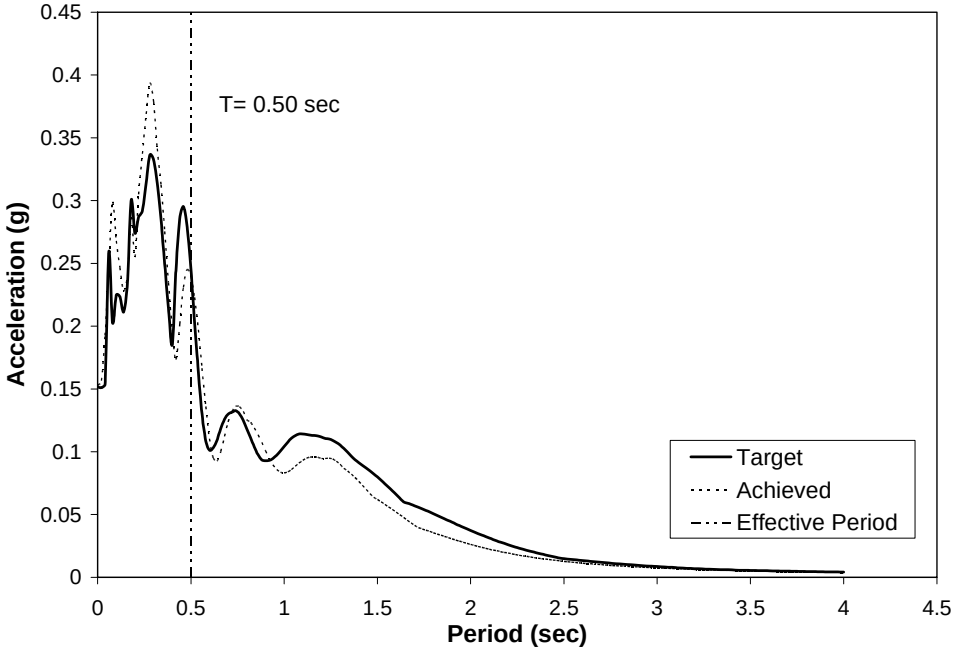


Fig. 3-69. Target vs. Achieved Ground Motion Spectra, Run-2 in SBR-1

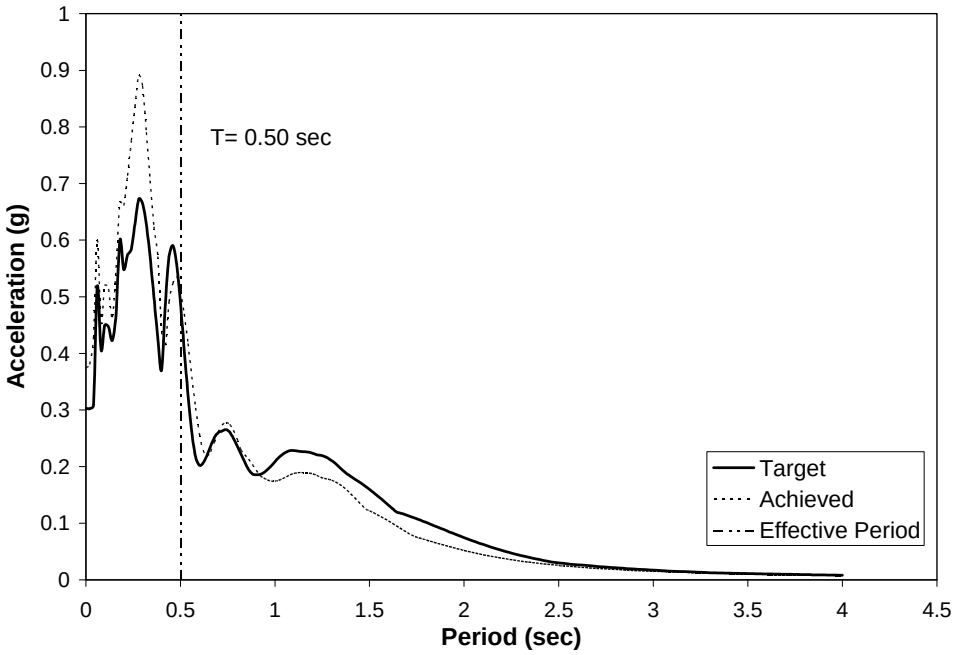


Fig. 3-70. Target vs. Achieved Ground Motion Spectra, Run-3 in SBR-1

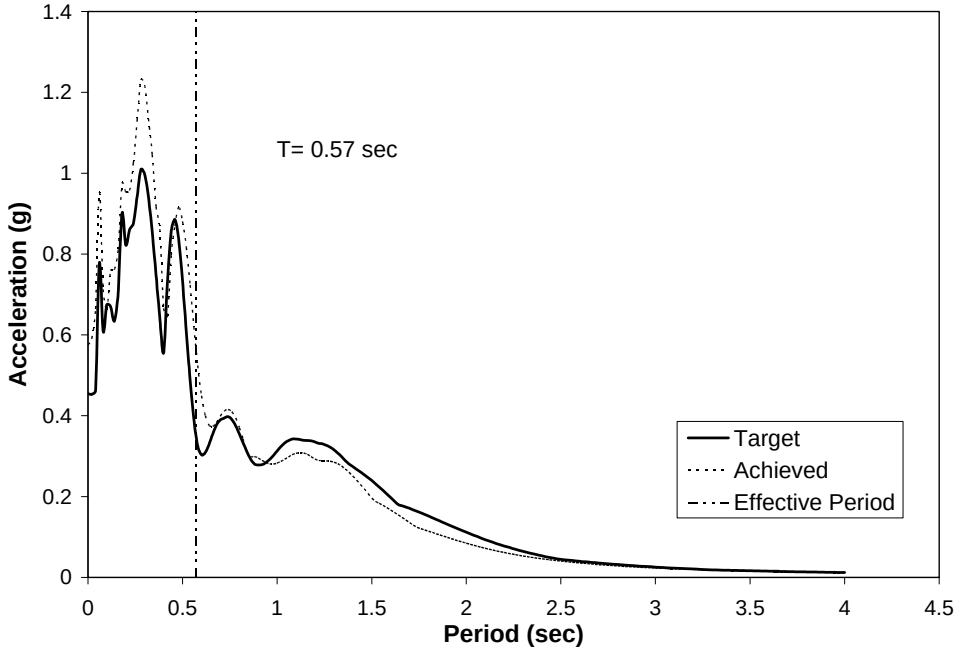


Fig. 3-71. Target vs. Achieved Ground Motion Spectra, Run-4 in SBR-1

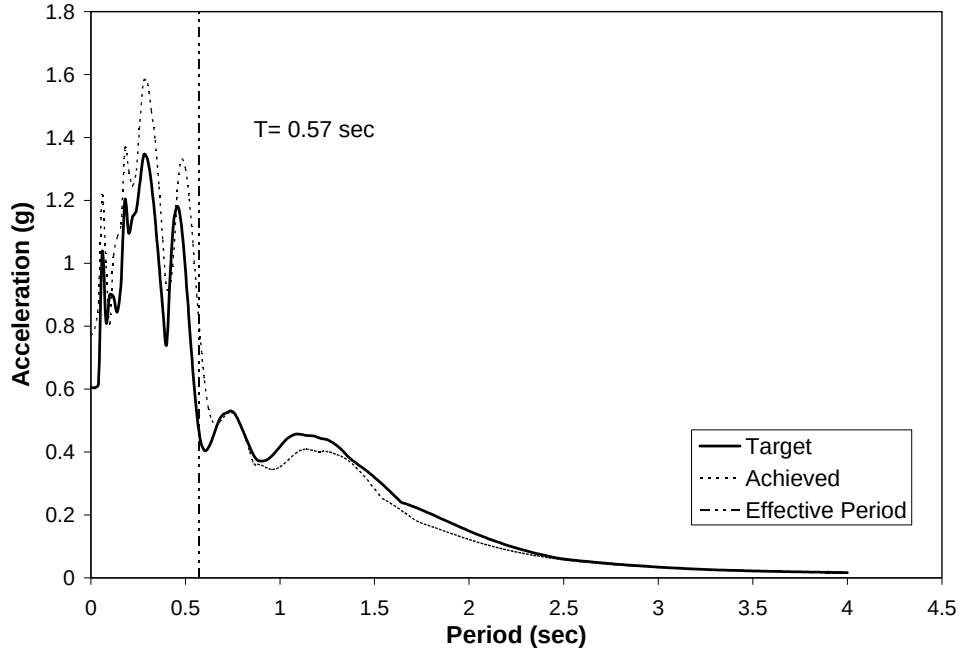


Fig. 3-72. Target vs. Achieved Ground Motion Spectra, Run-5 in SBR-1

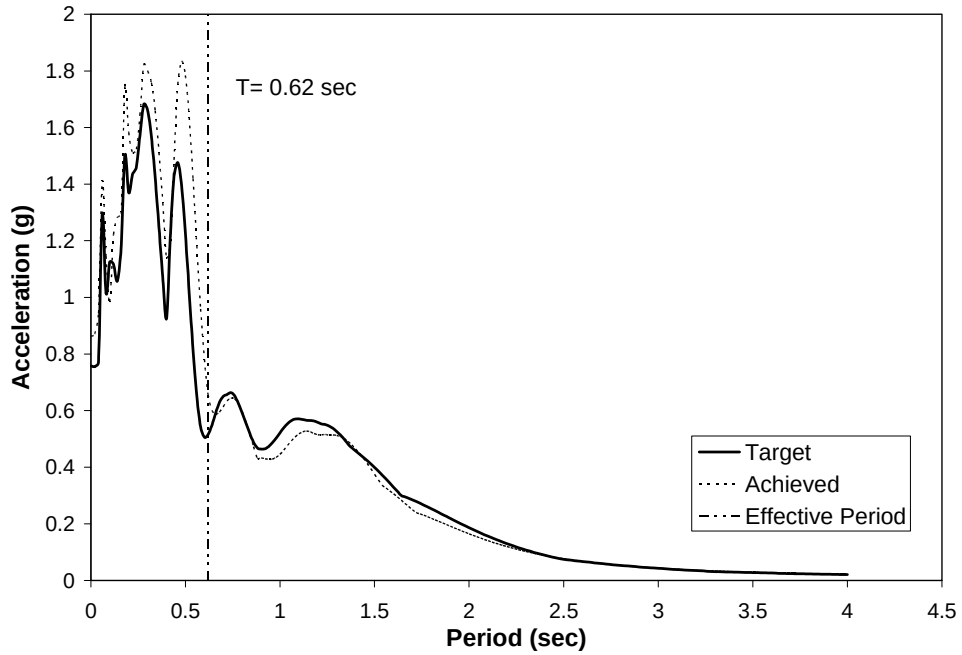


Fig. 3-73. Target vs. Achieved Ground Motion Spectra, Run-6 in SBR-1

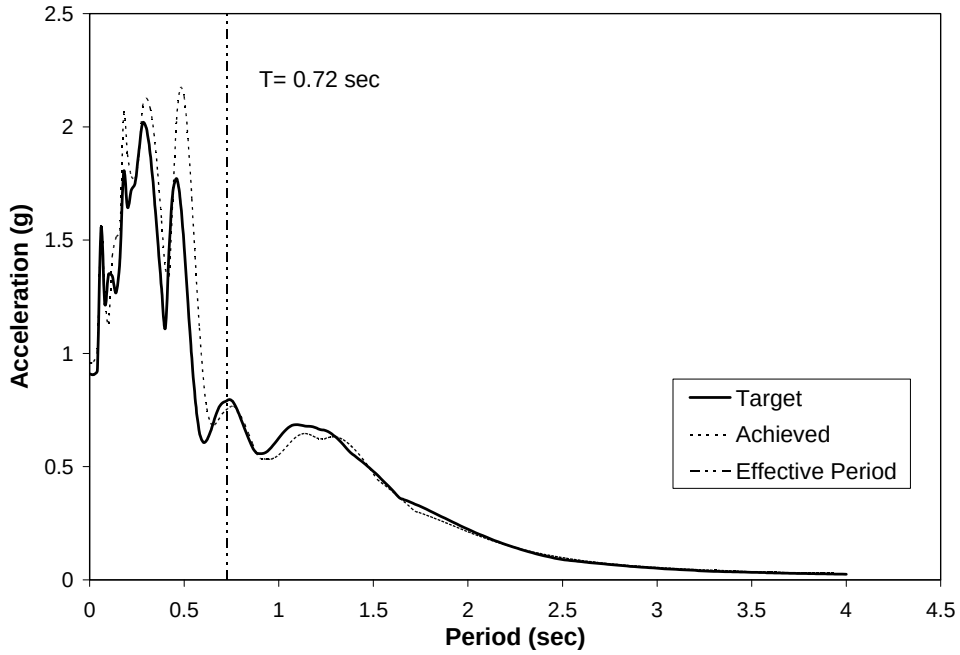
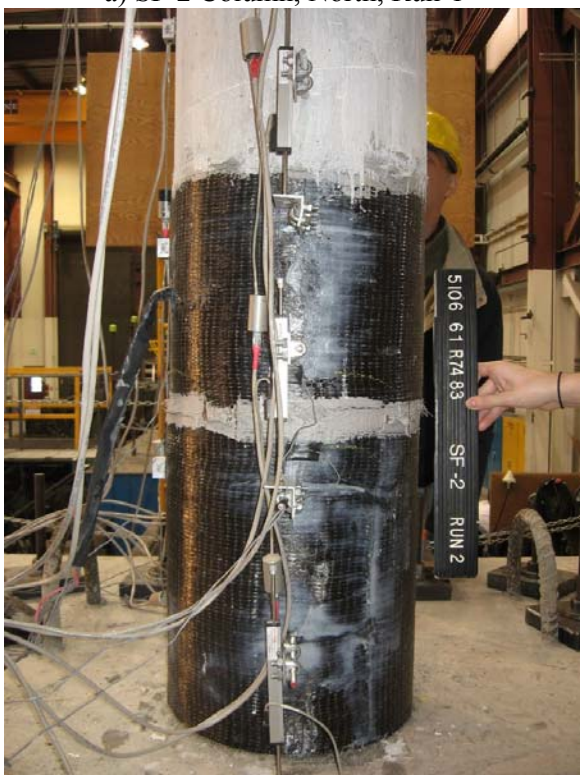


Fig. 3-74. Target vs. Achieved Ground Motion Spectra, Run-7 in SBR-1

a) SF-2 Column, North, Run-1

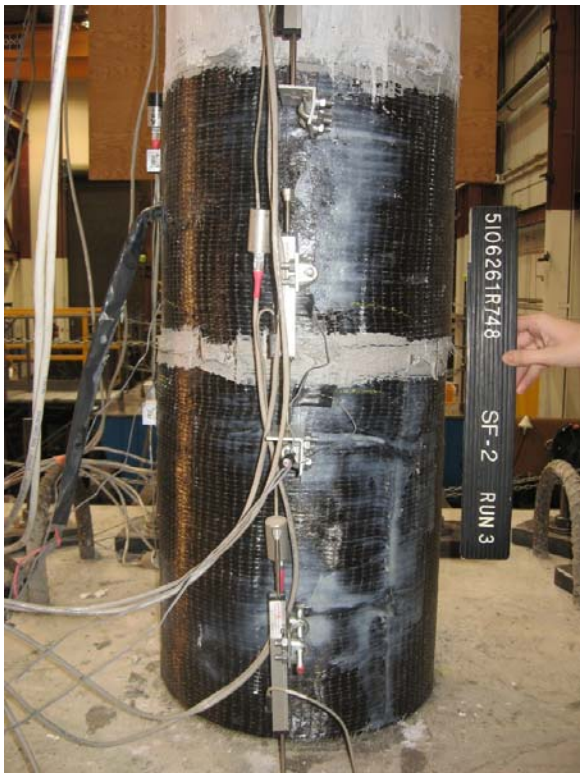
b) SF-2 Column, South, Run-1



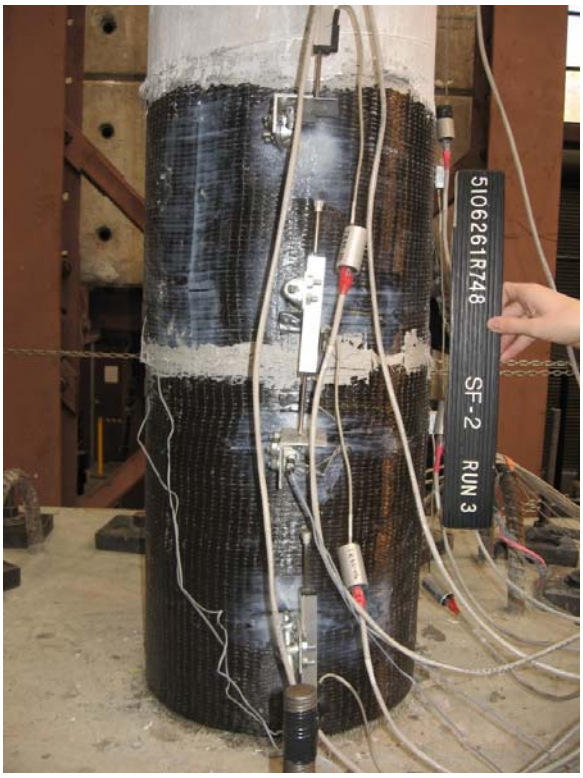
c) SF-2 Column, North, Run-2

d) SF-2 Column, South, Run-2

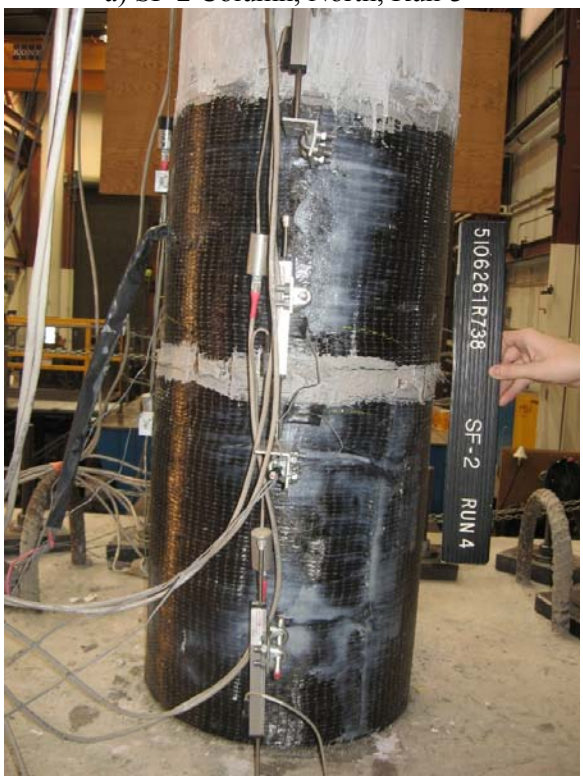
Fig. 3-75. Damage Progression Photographs for SF-2 Column, Bottom, Run 1 and 2



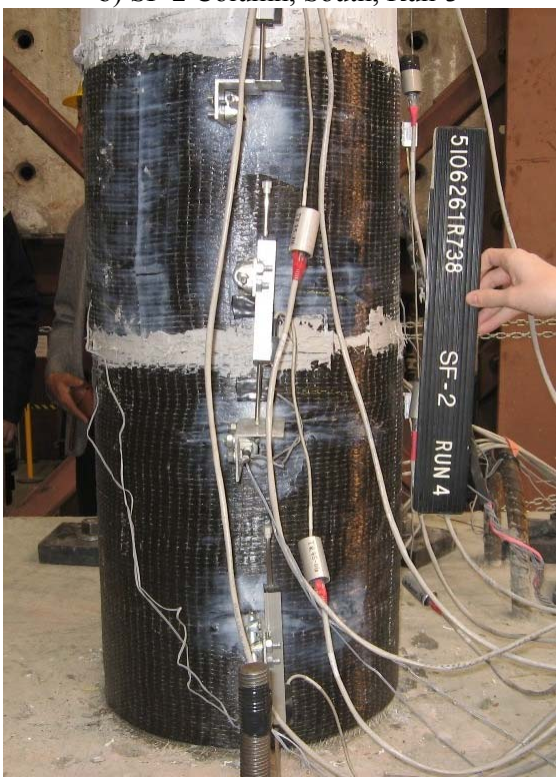
a) SF-2 Column, North, Run-3



b) SF-2 Column, South, Run-3

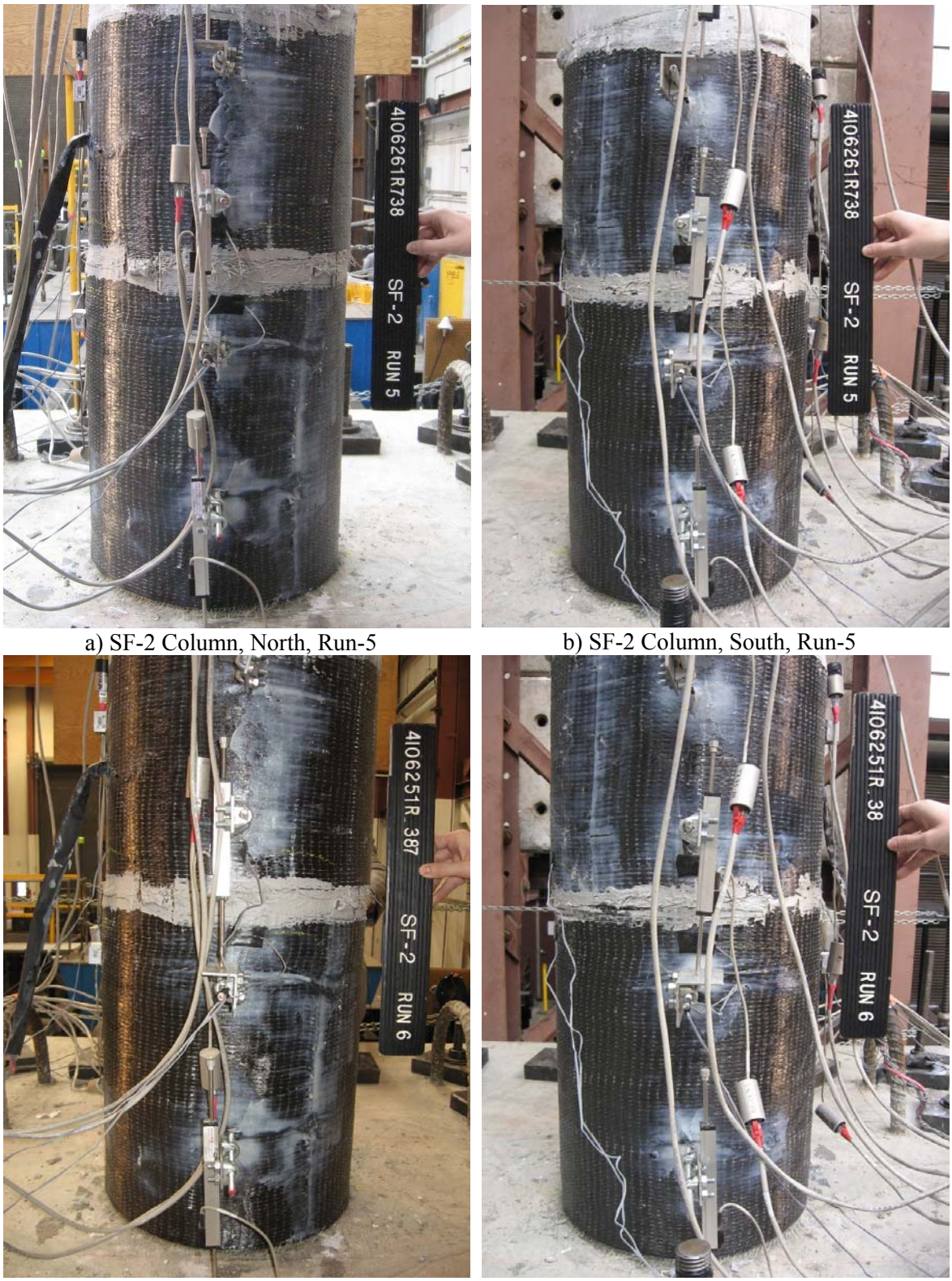


c) SF-2 Column, North, Run-4



d) SF-2 Column, South, Run-4

Fig. 3-76. Damage Progression Photographs for SF-2 Column, Bottom, Run 3 and 4



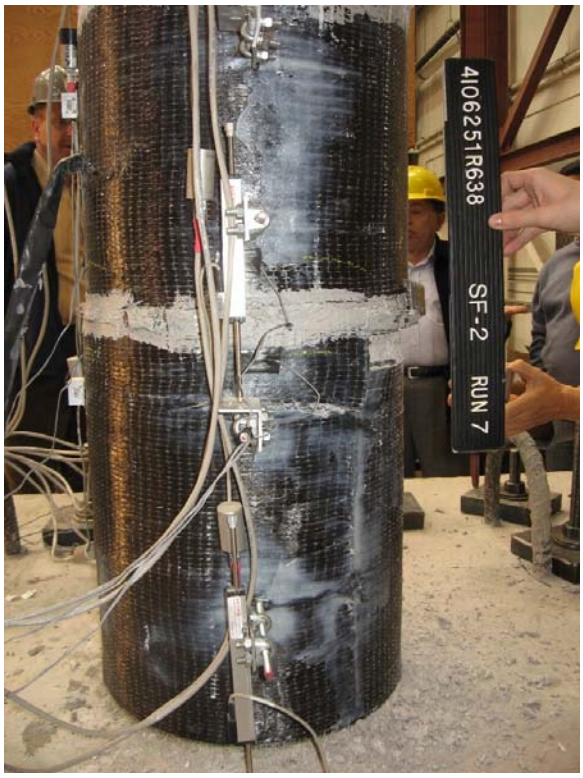
a) SF-2 Column, North, Run-5

b) SF-2 Column, South, Run-5

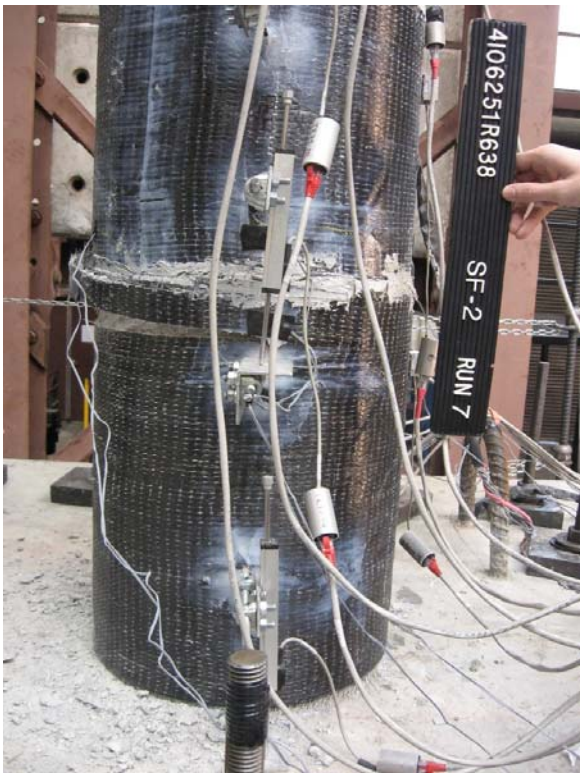
c) SF-2 Column, North, Run-6

d) SF-2 Column, South, Run-6

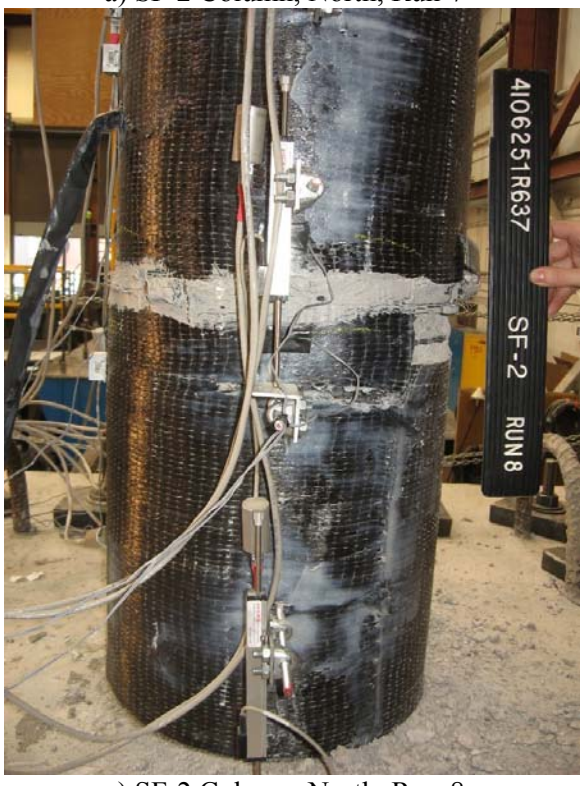
Fig. 3-77. Damage Progression Photographs for SF-2 Column, Bottom, Run 5 and 6



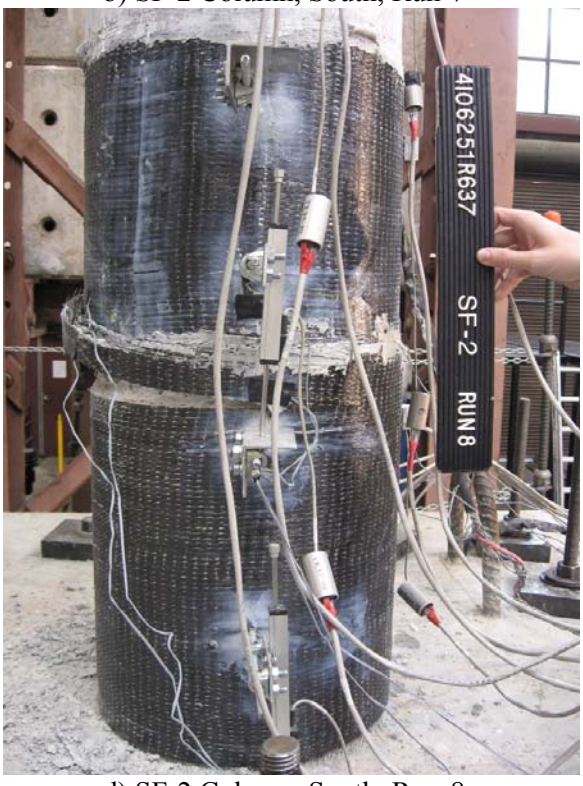
a) SF-2 Column, North, Run-7



b) SF-2 Column, South, Run-7



c) SF-2 Column, North, Run-8



d) SF-2 Column, South, Run-8

Fig. 3-78. Damage Progression Photographs for SF-2 Column, Bottom, Run 7 and 8

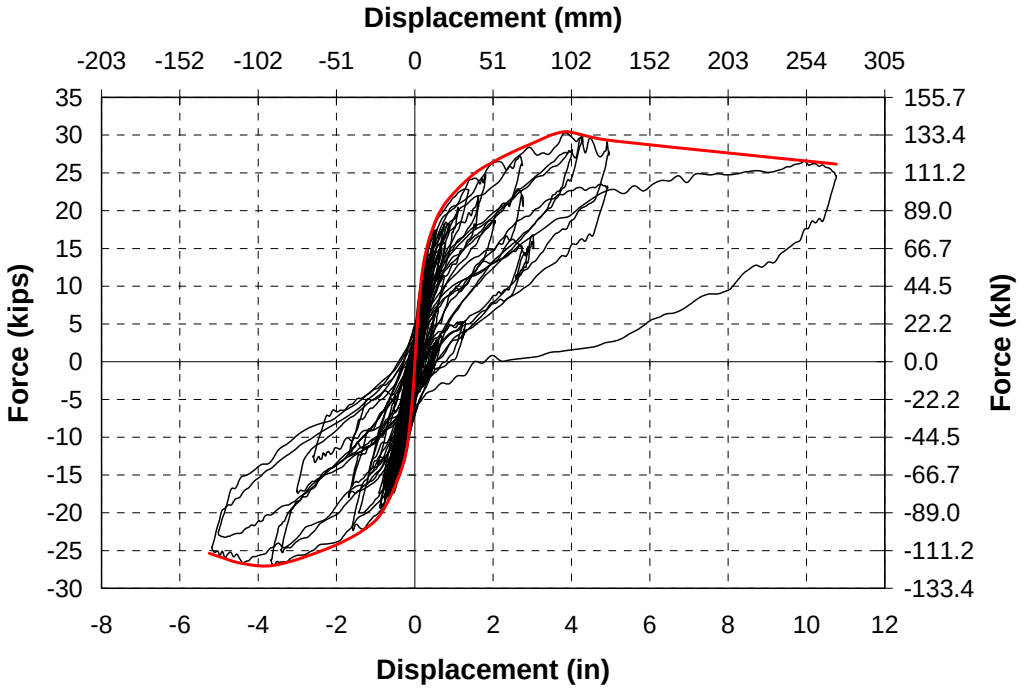


Fig. 3-79. Accumulated Force-Displacement Hysteresis Curve for SF-2

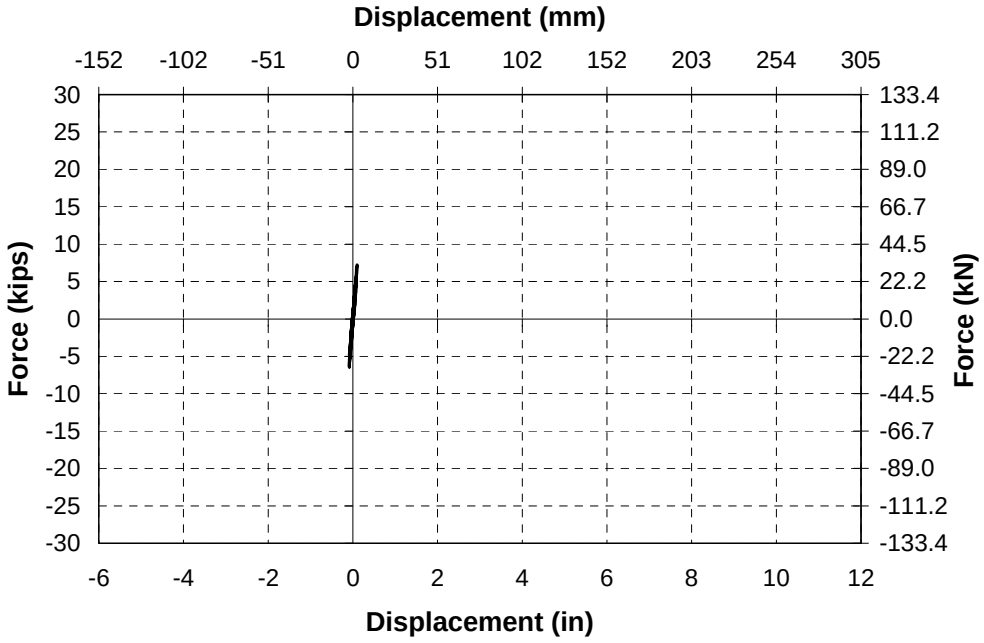


Fig. 3-80. Force-Displacement Hysteresis Curve for Run 1 in SF-2

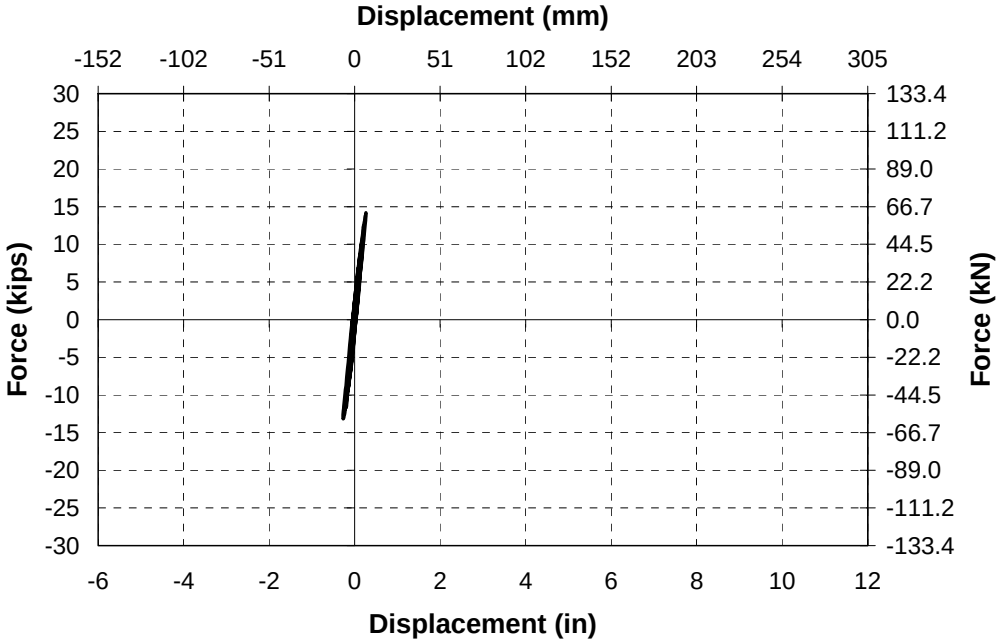


Fig. 3-81. Force-Displacement Hysteresis Curve for Run 2 in SF-2

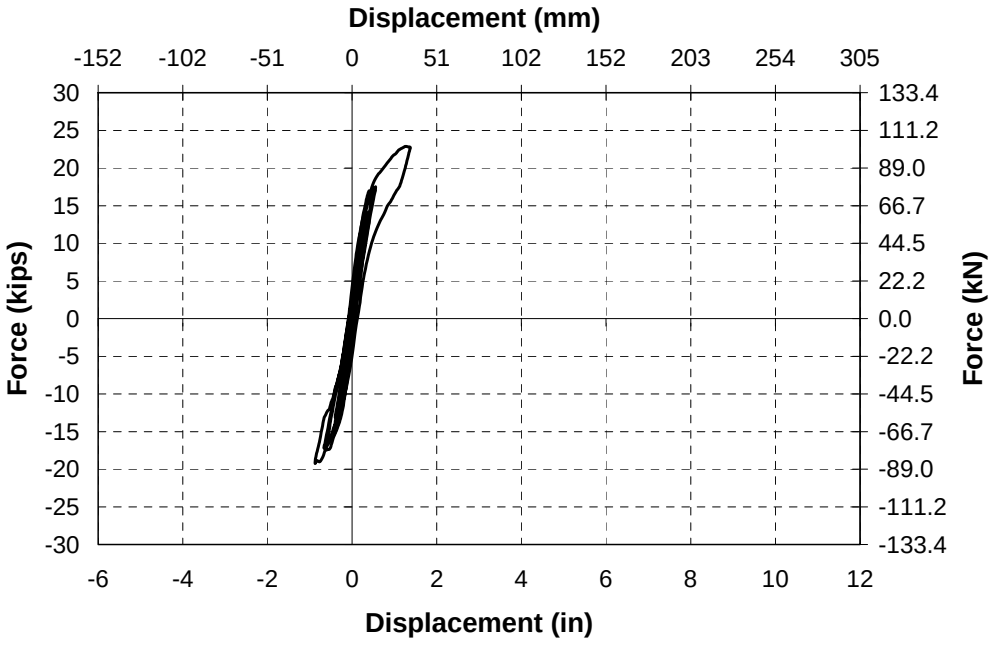


Fig. 3-82. Force-Displacement Hysteresis Curve for Run 3 in SF-2

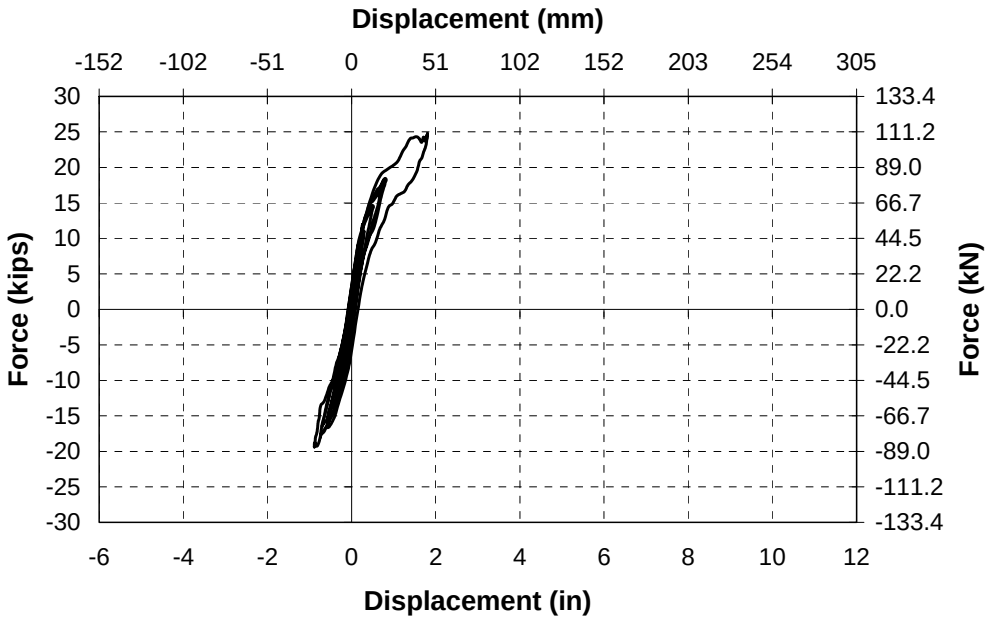


Fig. 3-83. Force-Displacement Hysteresis Curve for Run 4 in SF-2

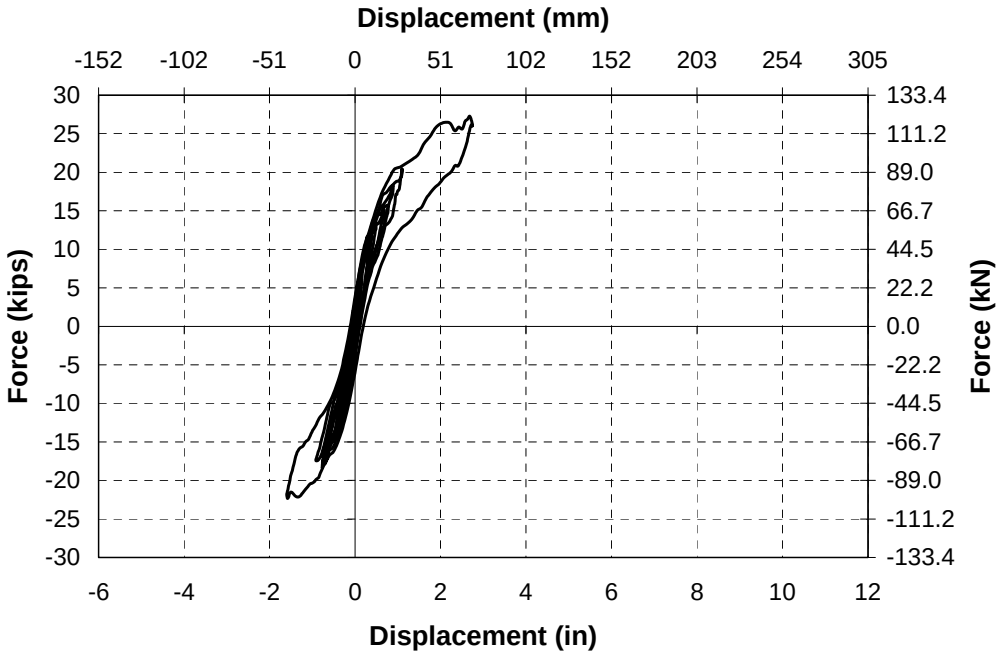


Fig. 3-84. Force-Displacement Hysteresis Curve for Run 5 in SF-2

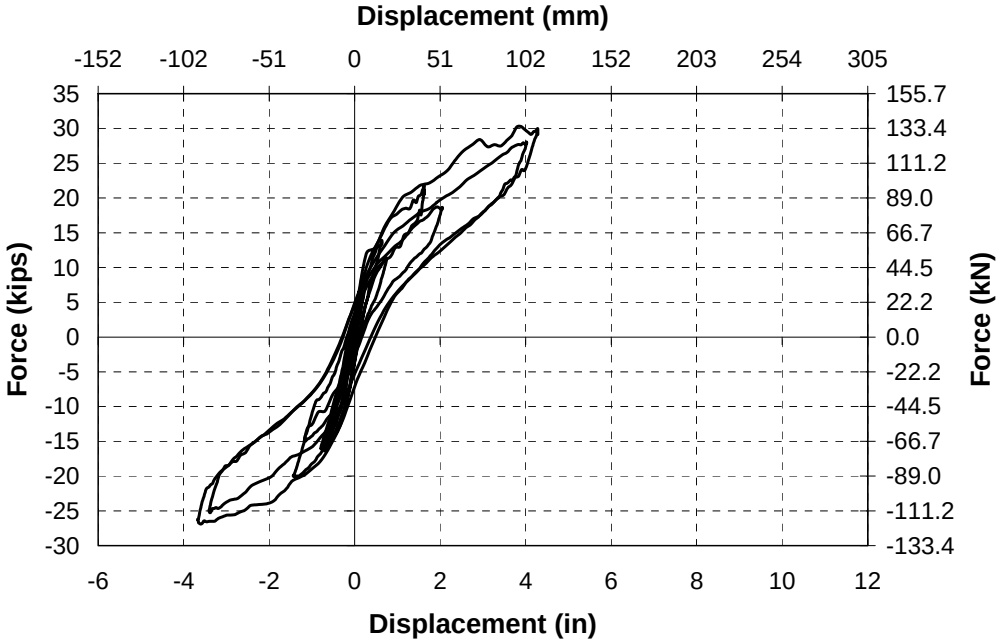


Fig. 3-85. Force-Displacement Hysteresis Curve for Run 6 in SF-2

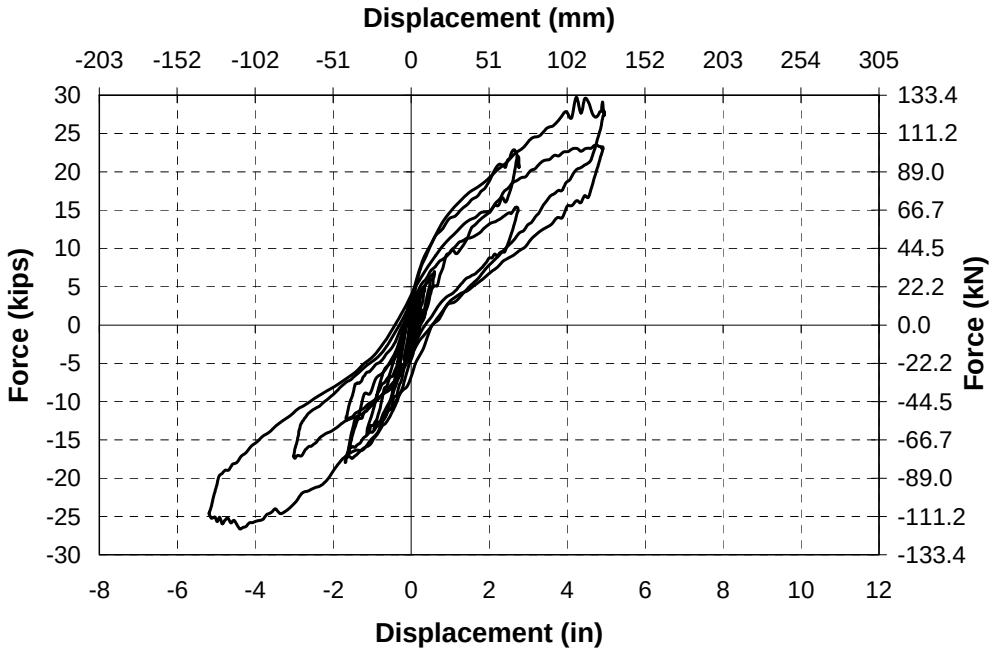


Fig. 3-86. Force-Displacement Hysteresis Curve for Run 7 in SF-2

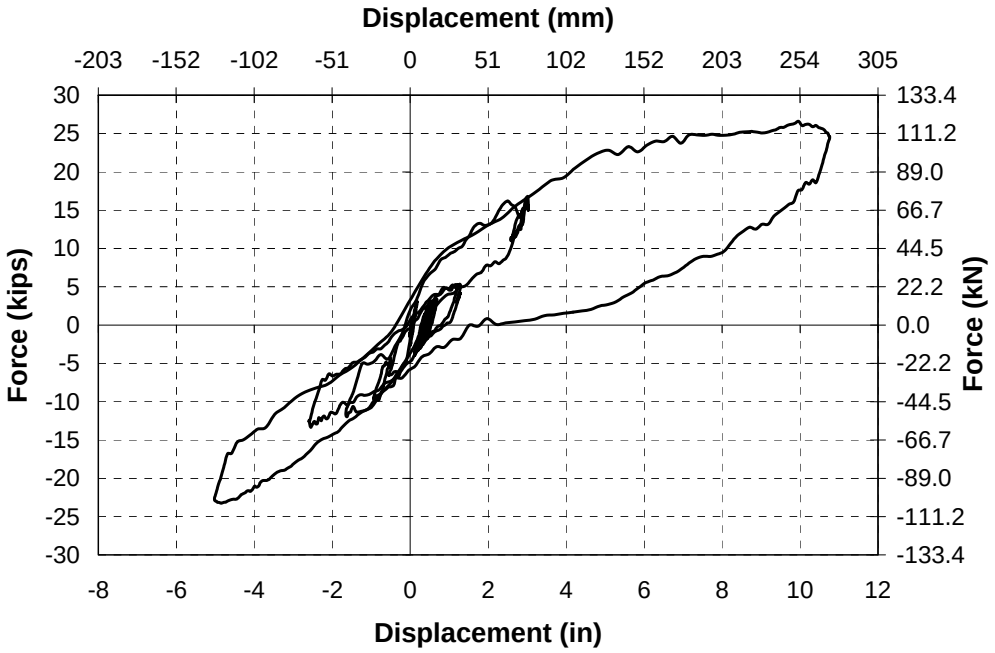


Fig. 3-87. Force-Displacement Hysteresis Curve for Run 8 in SF-2

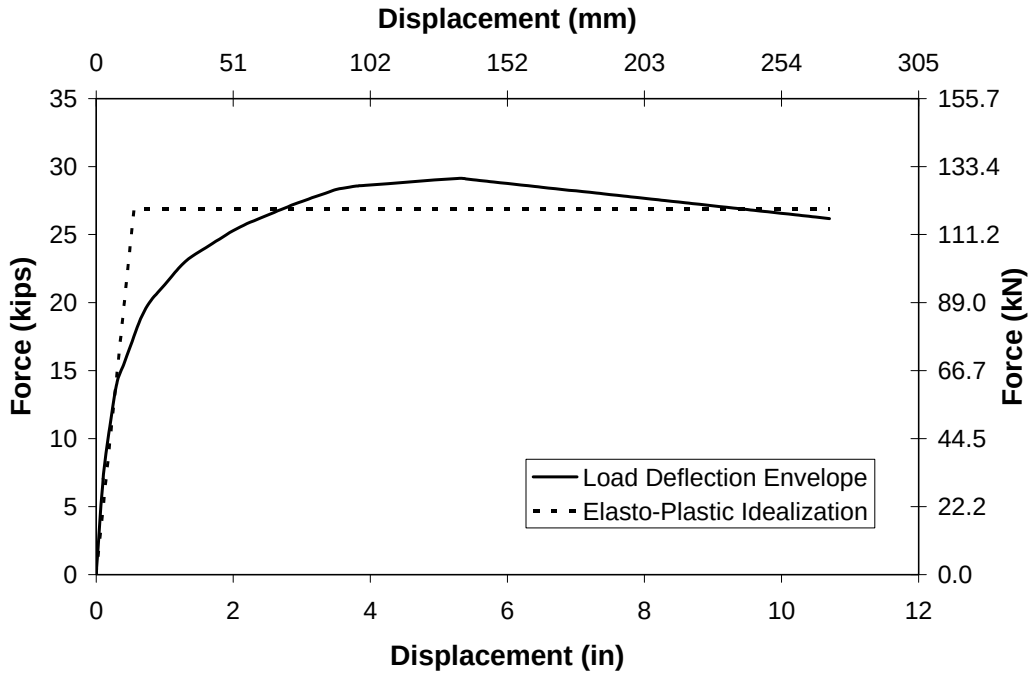


Fig. 3-88. Backbone Curve of SF-2

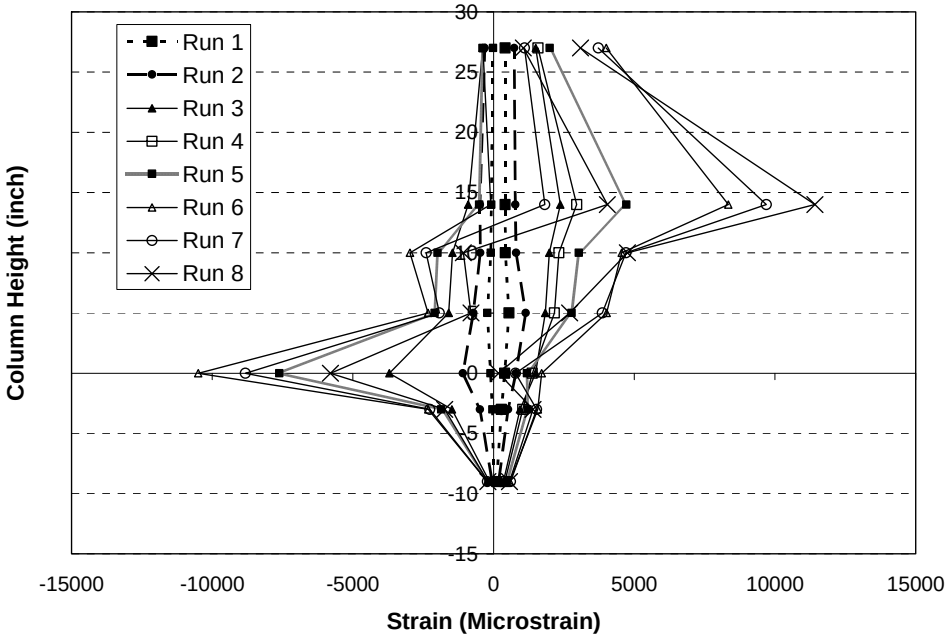


Fig. 3-89. The Max. and Min. Long. Strain Profile of the SF-2

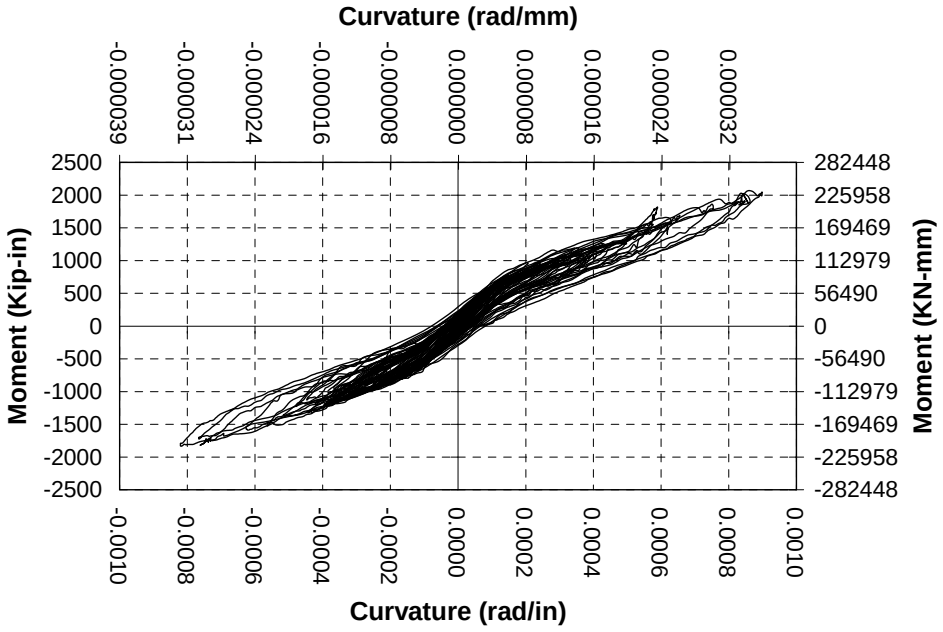


Fig. 3-90. Accumulated Moment Curvature at the First Level in SF-2

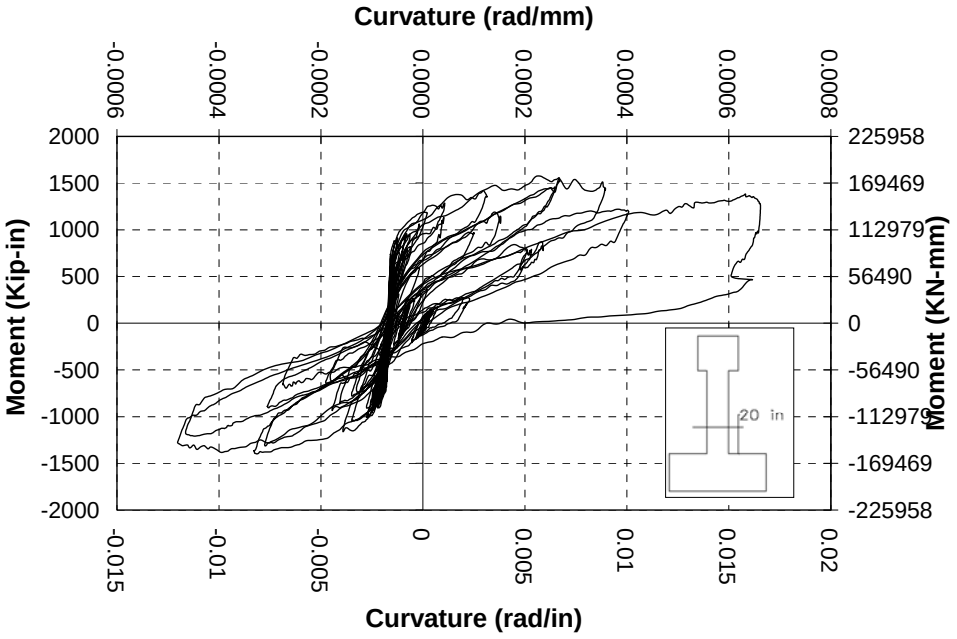


Fig. 3-91. Accumulated Moment Curvature at the Second Level in SF-2

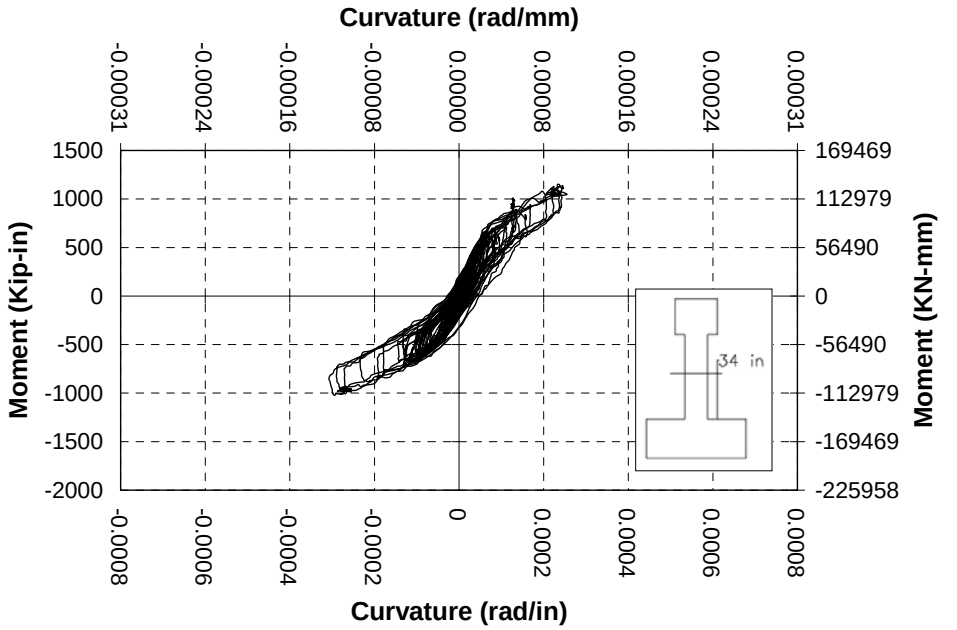


Fig. 3-92. Accumulated Moment Curvature at the Third Level in SF-2

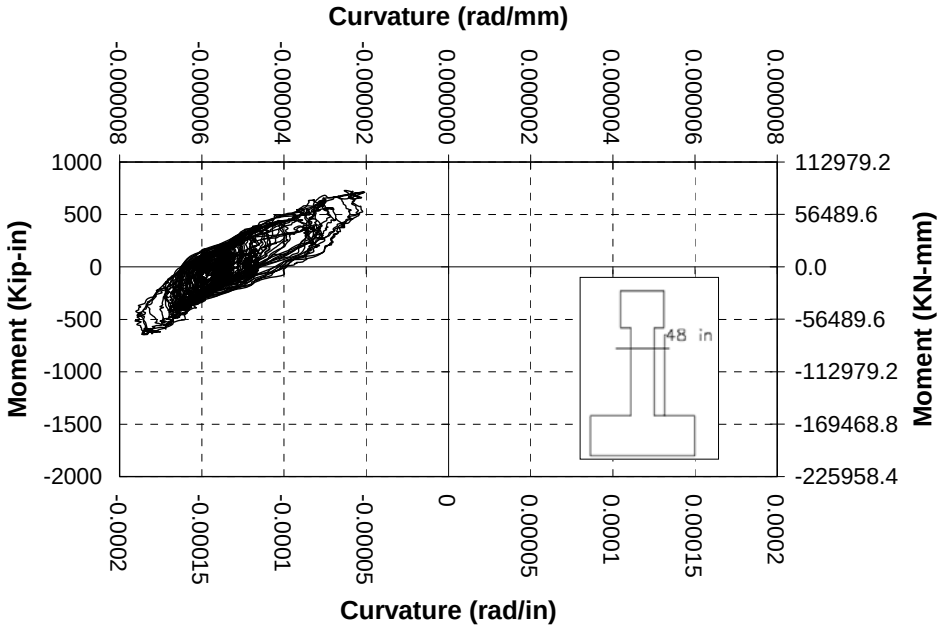


Fig. 3-93. Accumulated Moment Curvature at the Fourth Level in SF-2

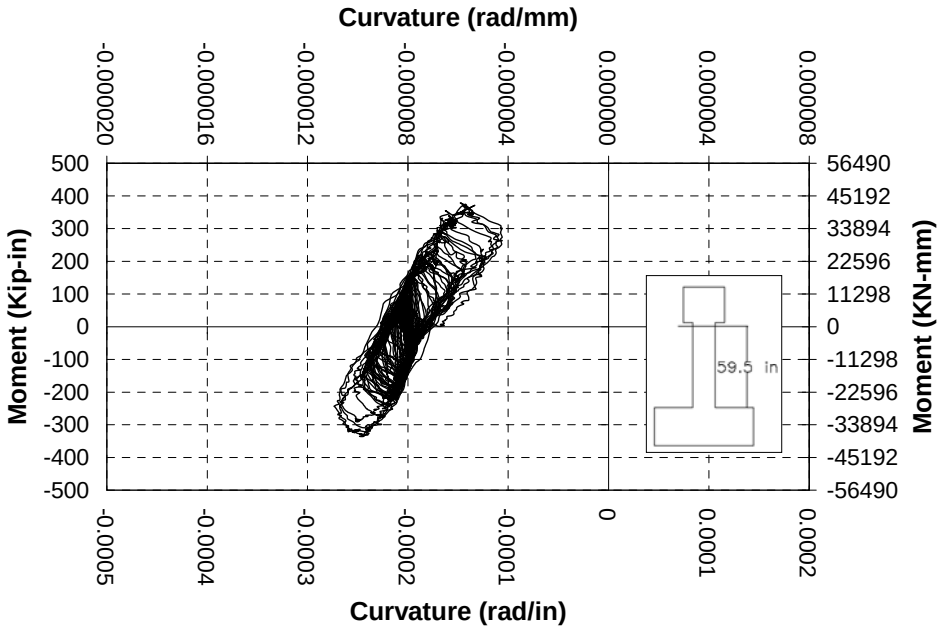


Fig. 3-94. Accumulated Moment Curvature at the Fifth Level in SF-2

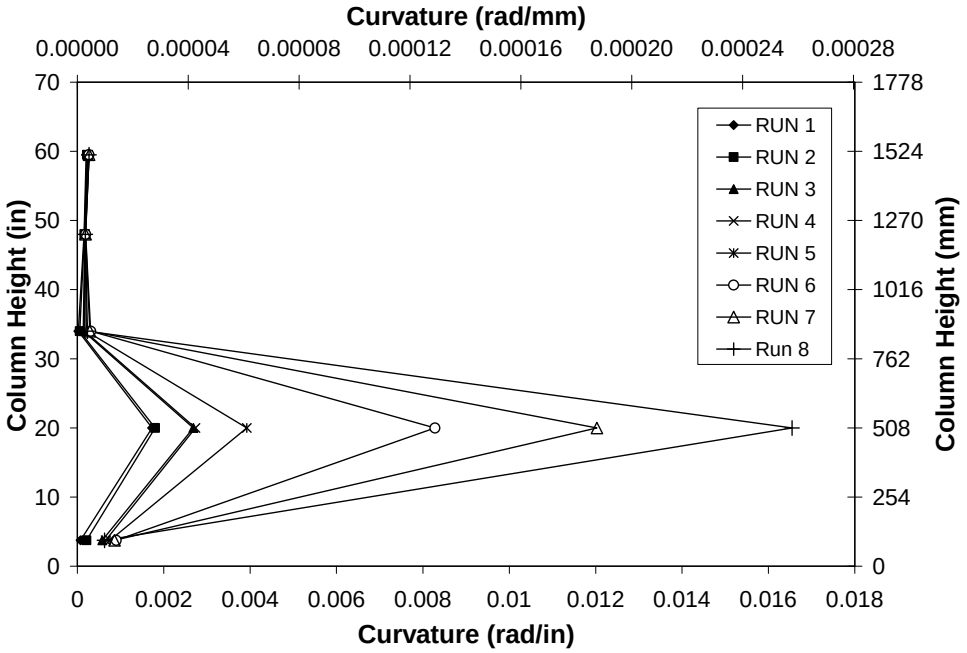


Fig. 3-95. Curvature Profile for SF-2

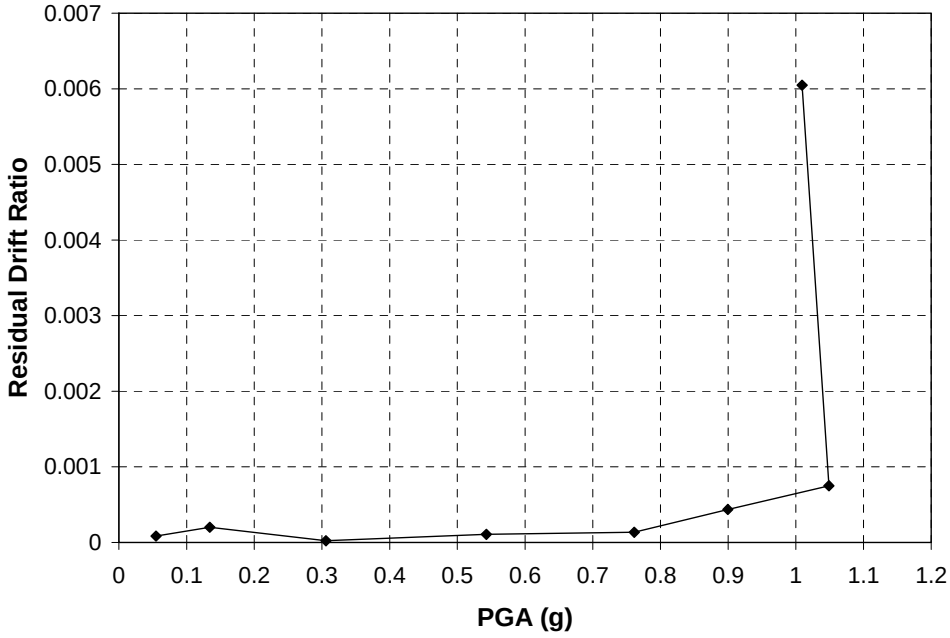


Fig. 3-96. Residual Drift Ratio vs. PGA in SF-2

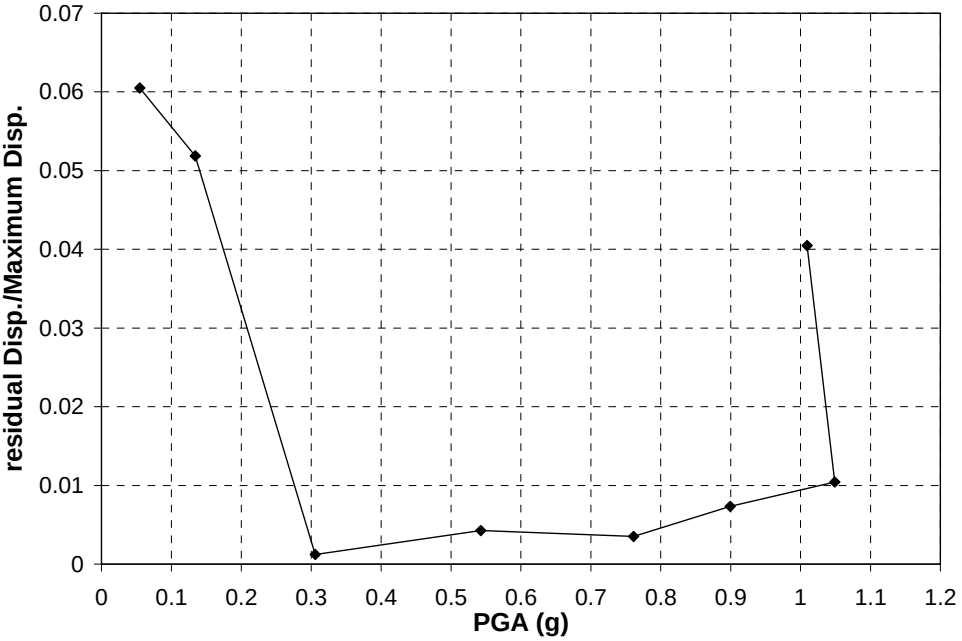


Fig. 3-97. Residual Disp. / Max. Disp. vs. PGA in SF-2

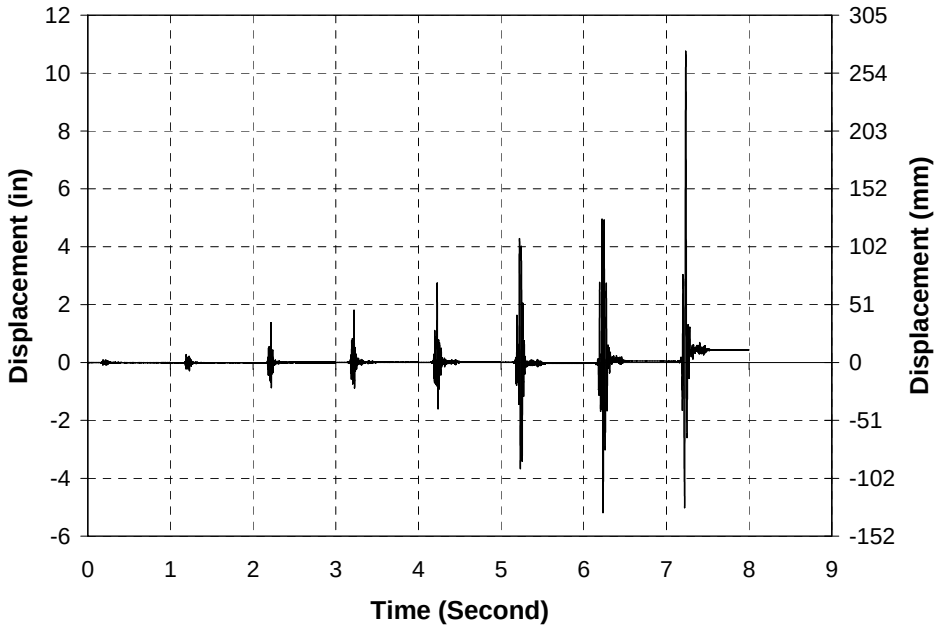


Fig. 3-98. Displacement History in Column SF-2

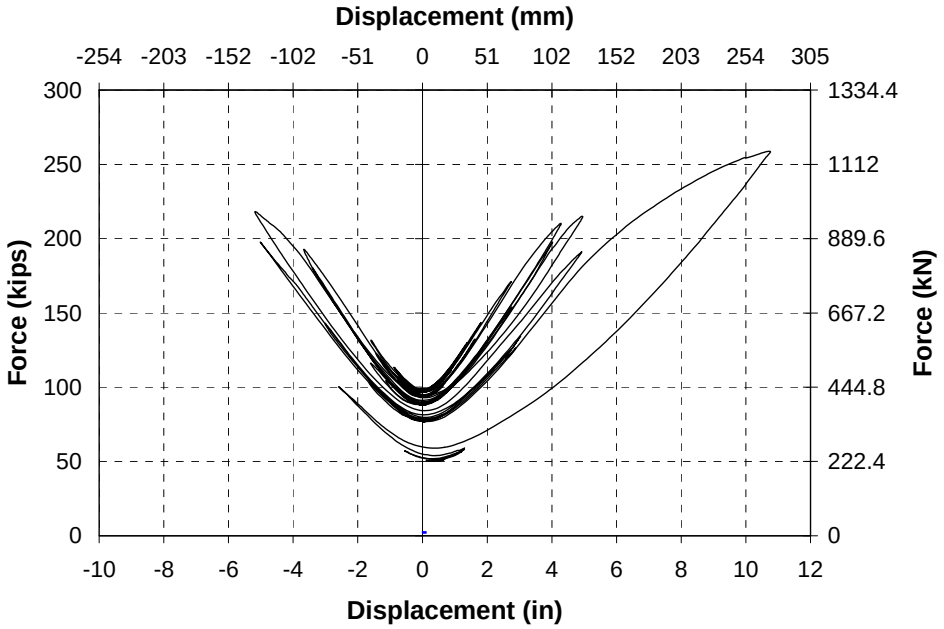


Fig. 3-99. Unbonded PT Rod Force vs. Displacement in SF-2

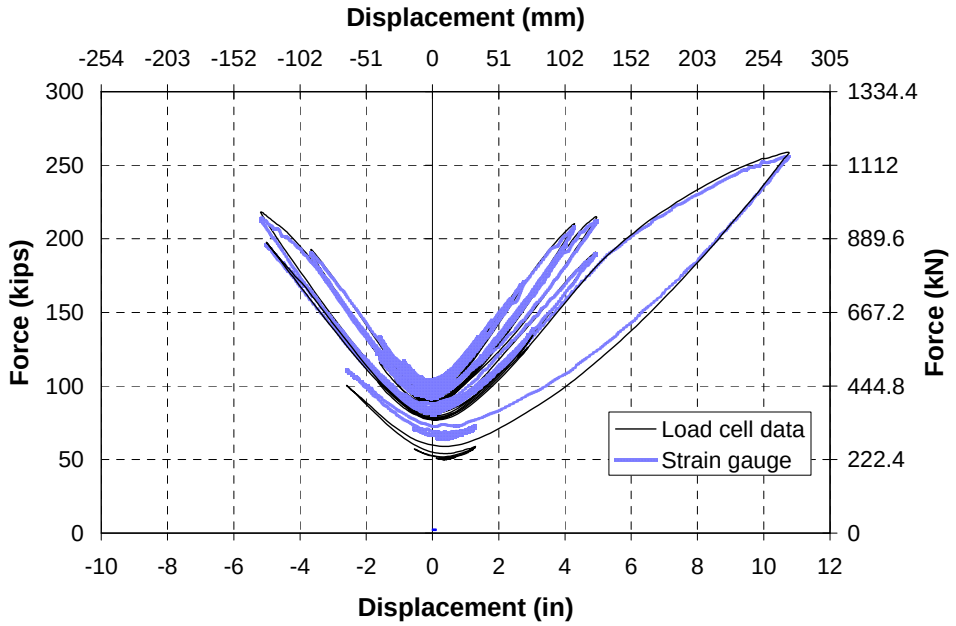


Fig. 3-100. Comparison of Unbonded PT Rod Force Measured by Load Cell and Strain Gauges in SF-2

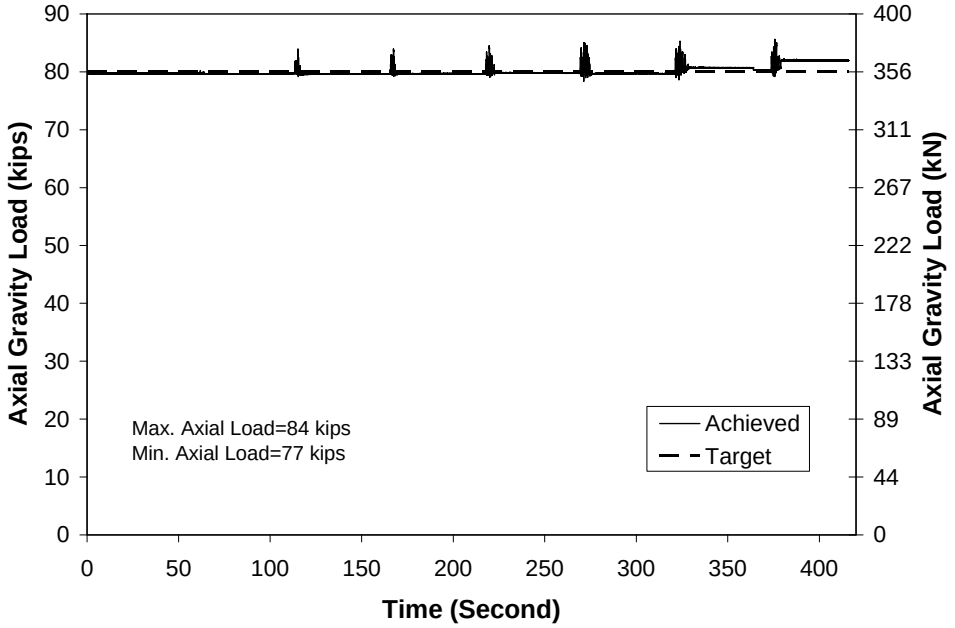


Fig. 3-101. Axial Gravity Load History on SF-2

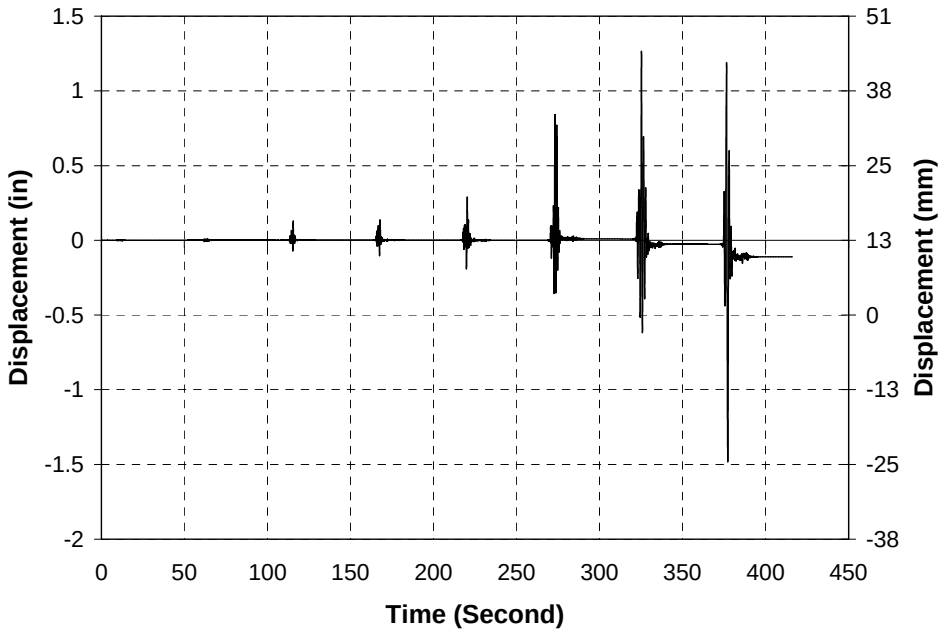


Fig. 3-102. History of Segment Separation at North Side of the SF-2

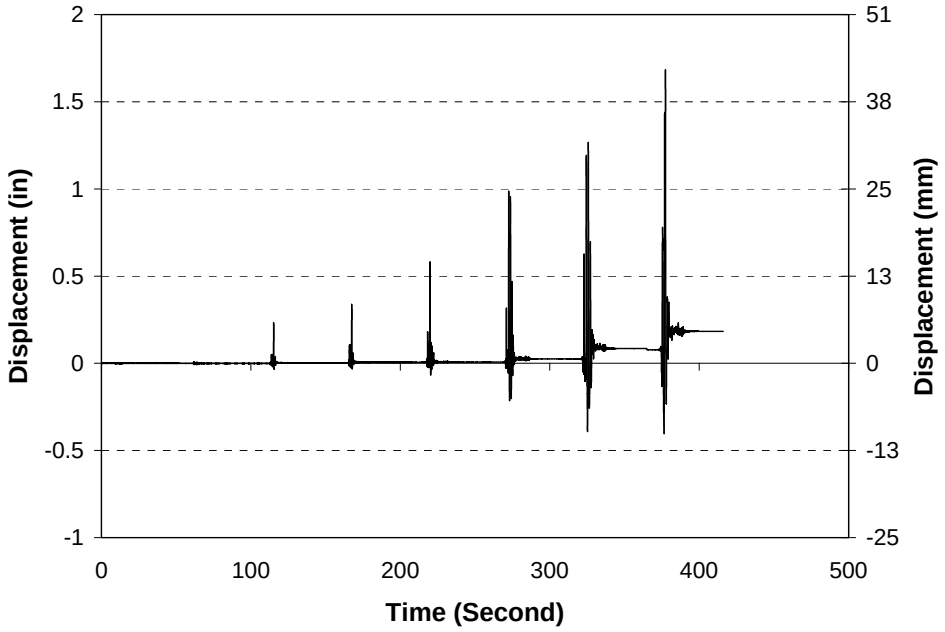
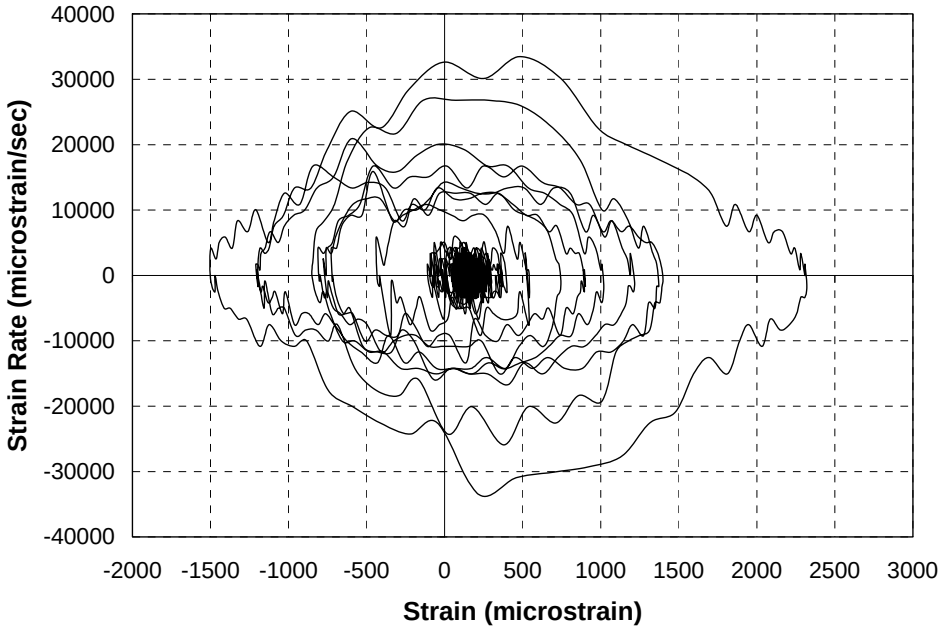
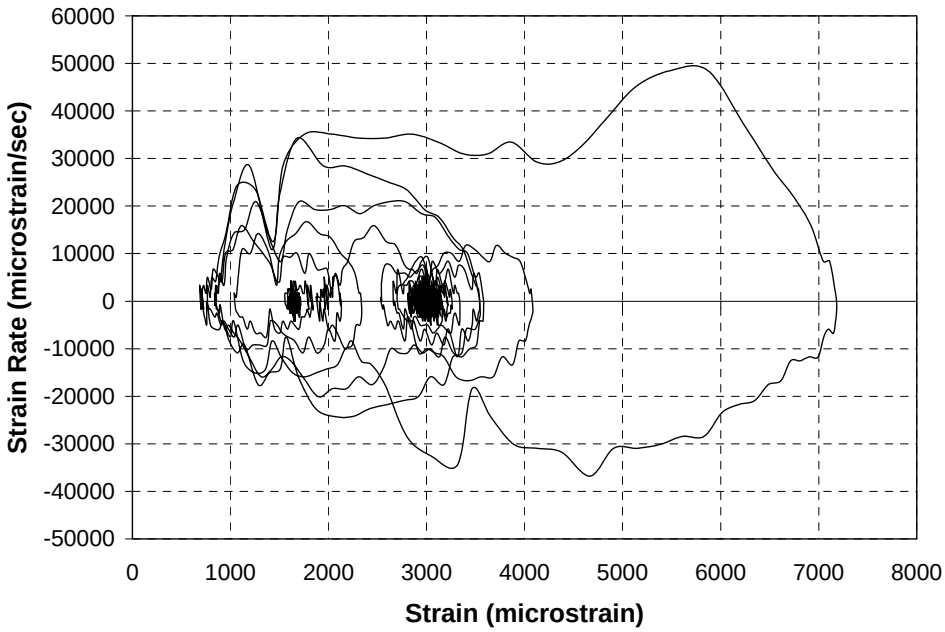


Fig. 3-103. History of Segment Separation at South Side of the SF-2



a)



b)

Fig. 3-104. Strain Rate vs. Strain in SF-2 a) Gauge 21, Run 3 b) Gauge 33, Run 4

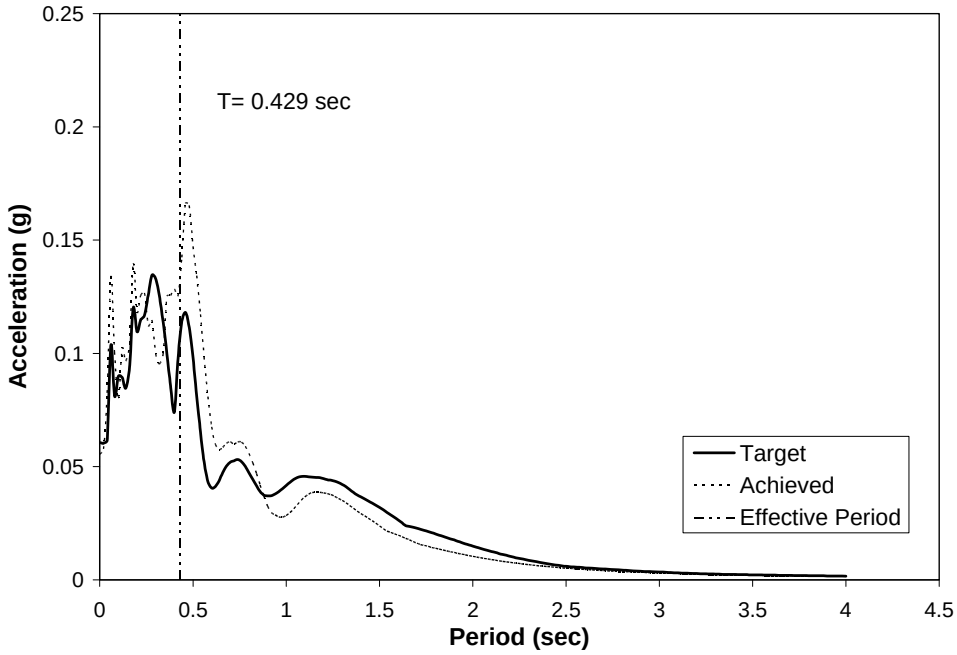


Fig. 3-105. Target vs. Achieved Ground Motion Spectra, Run-1 in SF-2

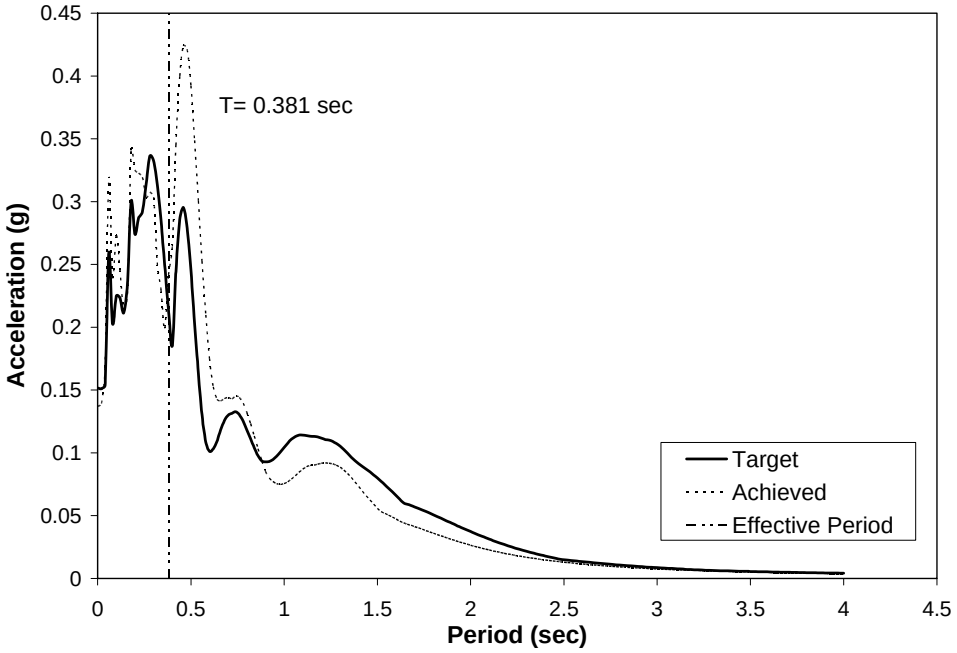


Fig. 3-106. Target vs. Achieved Ground Motion Spectra, Run-2 in SF-2

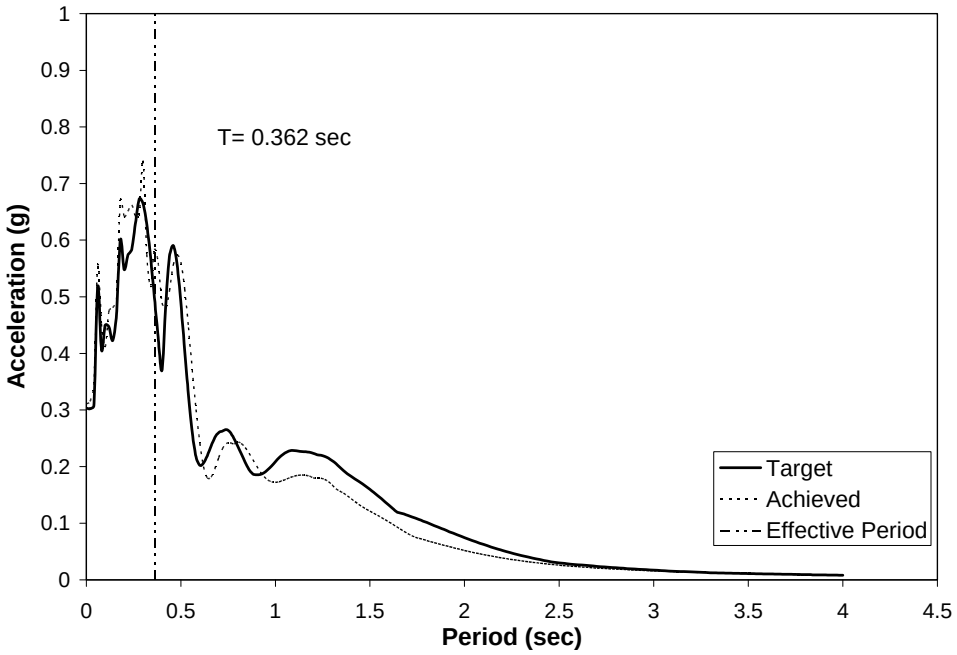


Fig. 3-107. Target vs. Achieved Ground Motion Spectra, Run-3 in SF-2

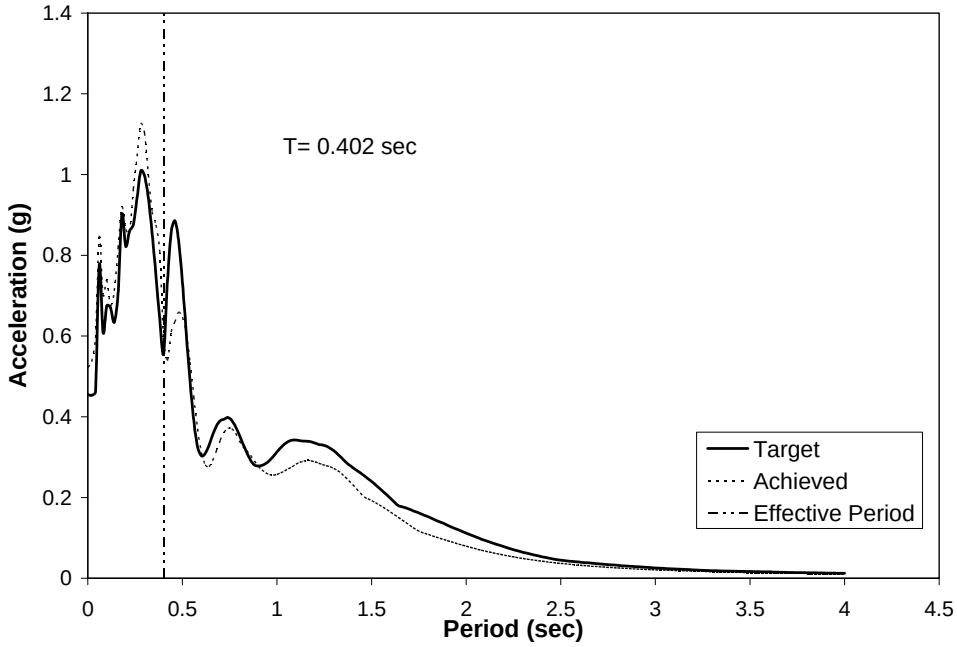


Fig. 3-108. Target vs. Achieved Ground Motion Spectra, Run-4 in SF-2

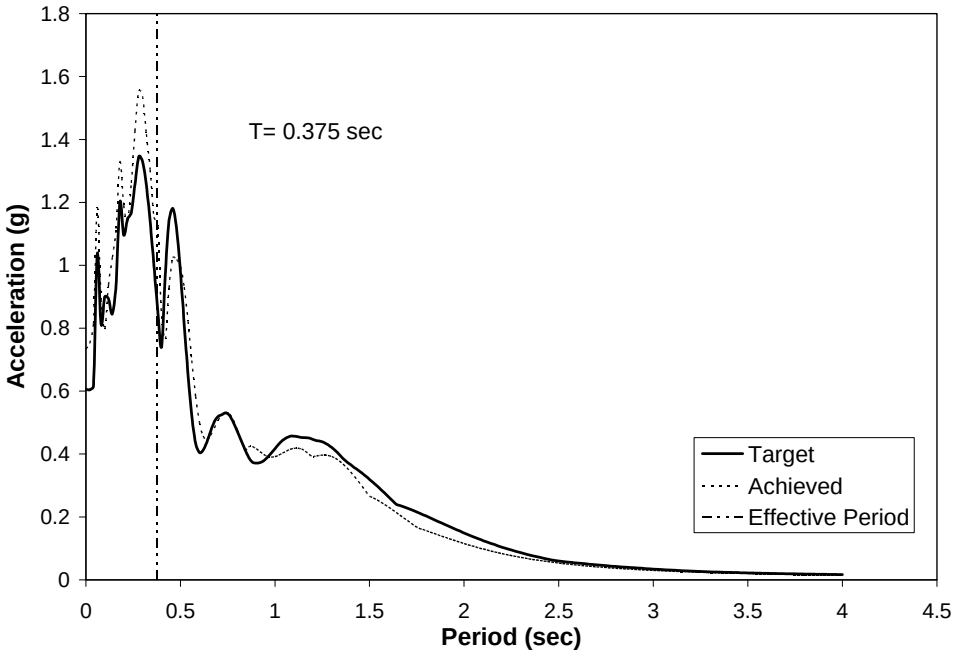


Fig. 3-109. Target vs. Achieved Ground Motion Spectra, Run-5 in SF-2

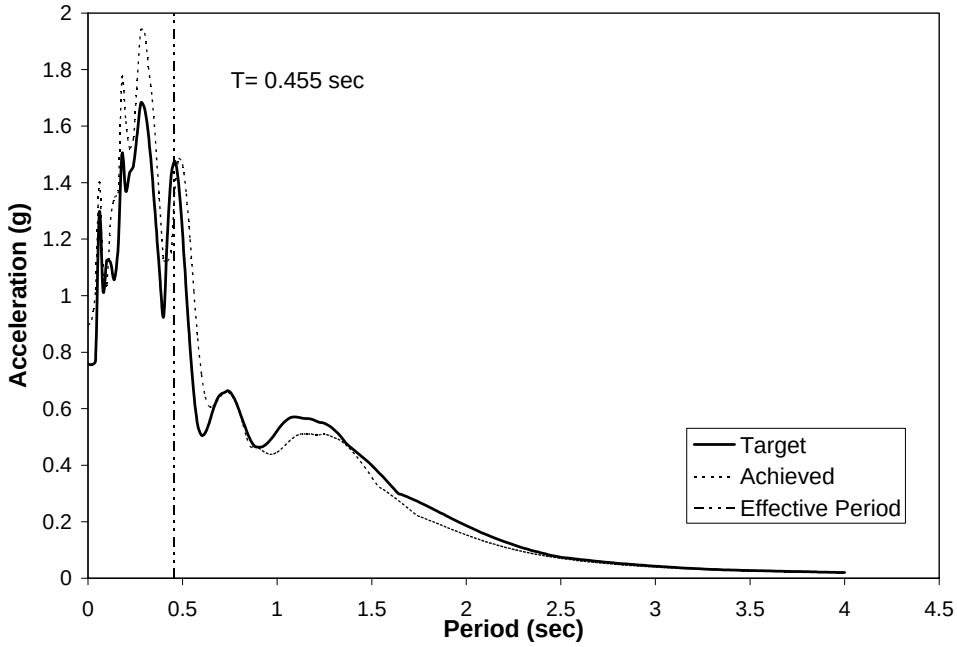


Fig. 3-110. Target vs. Achieved Ground Motion Spectra, Run-6 in SF-2

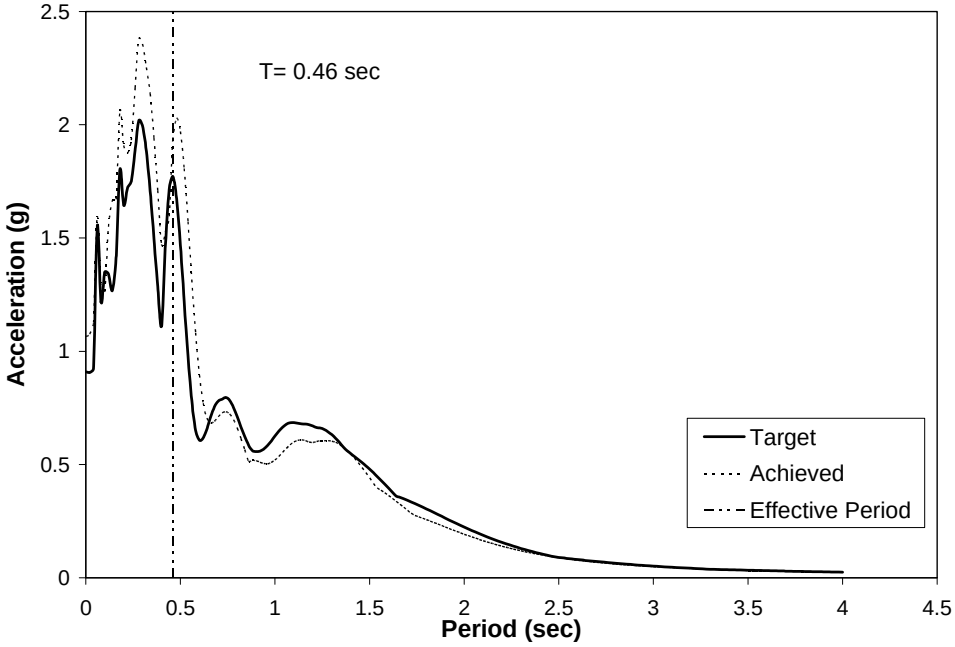


Fig. 3-111. Target vs. Achieved Ground Motion Spectra, Run-7 in SF-2

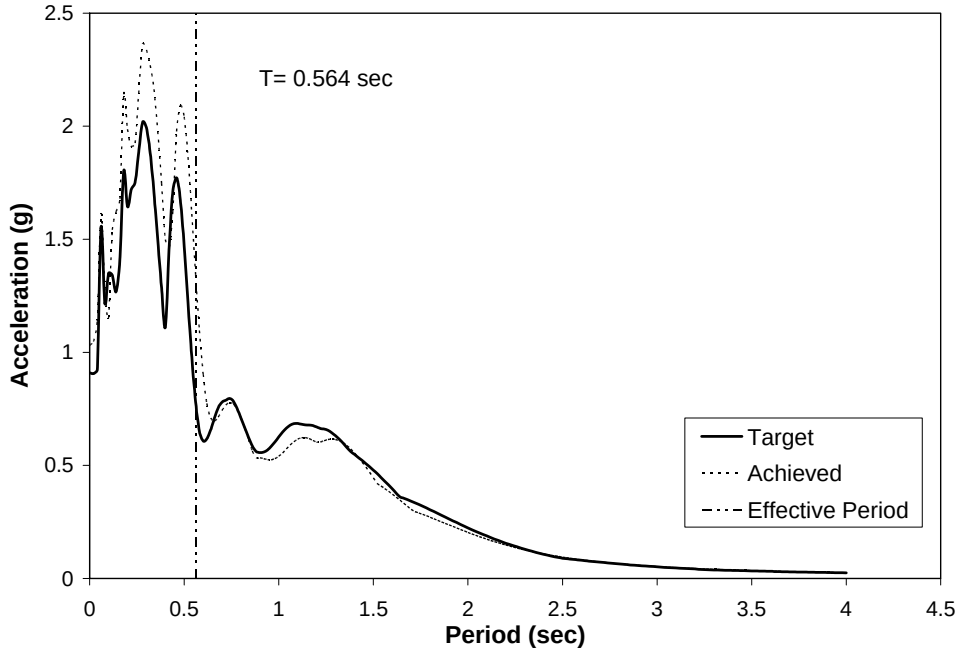
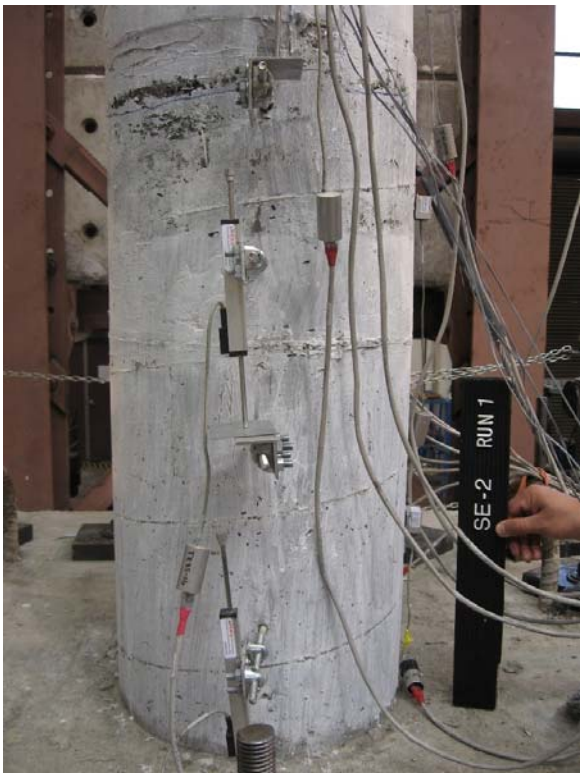


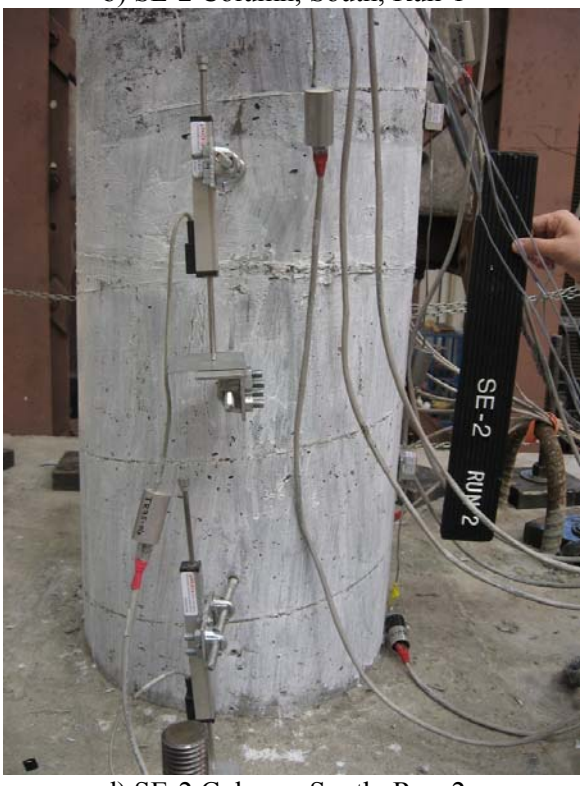
Fig. 3-112. Target vs. Achieved Ground Motion Spectra, Run-8 in SF-2

a) SE-2 Column, North, Run-1



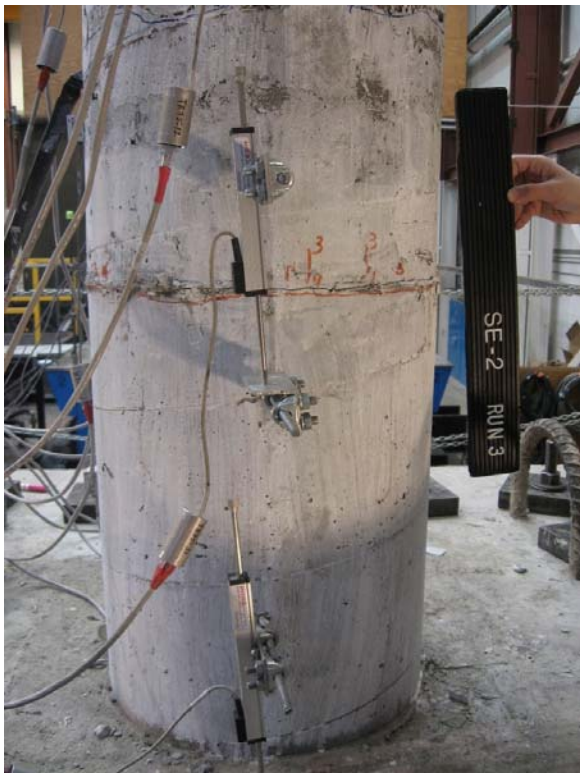
b) SE-2 Column, South, Run-1

c) SE-2 Column, North, Run-2

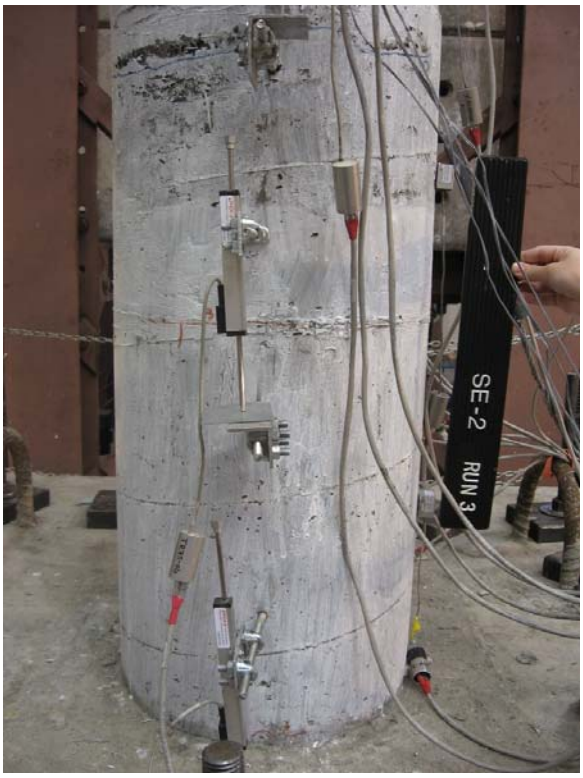


d) SE-2 Column, South, Run-2

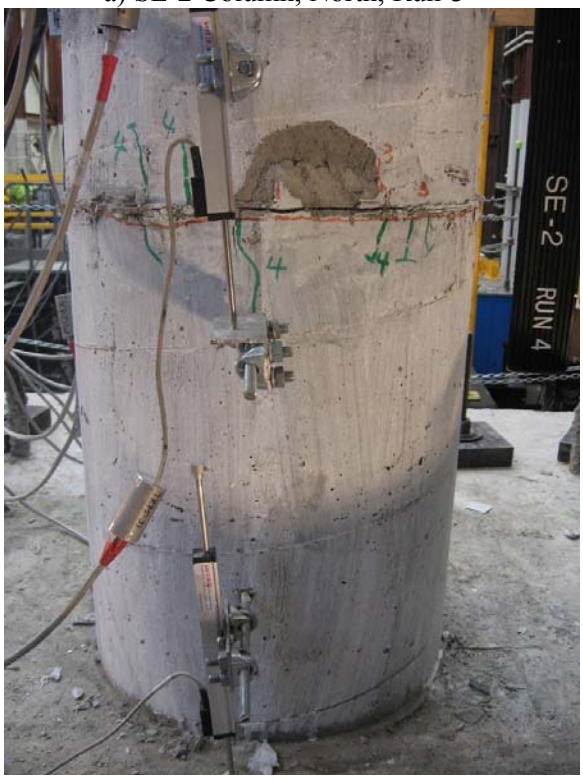
Fig. 3-113. Damage Progression Photographs for SE-2 Column, Bottom, Run 1 and 2



a) SE-2 Column, North, Run-3



b) SE-2 Column, South, Run-3

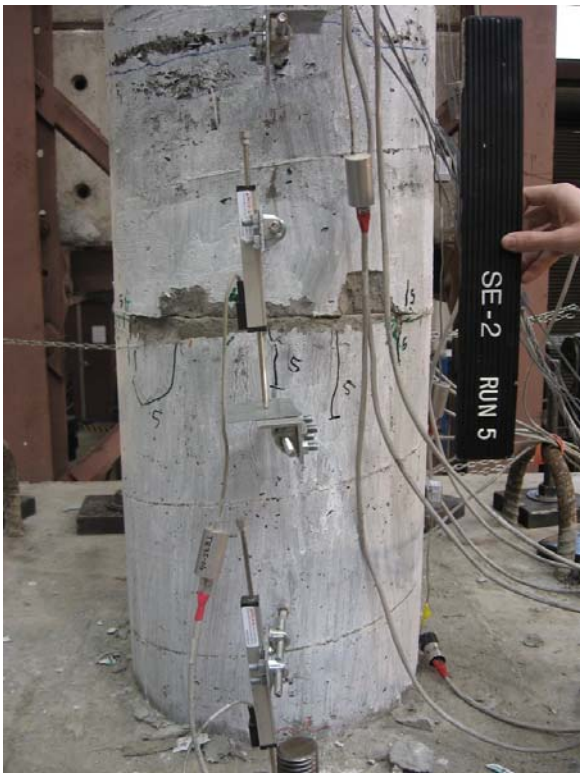


c) SE-2 Column, North, Run-4

d) SE-2 Column, South, Run-4

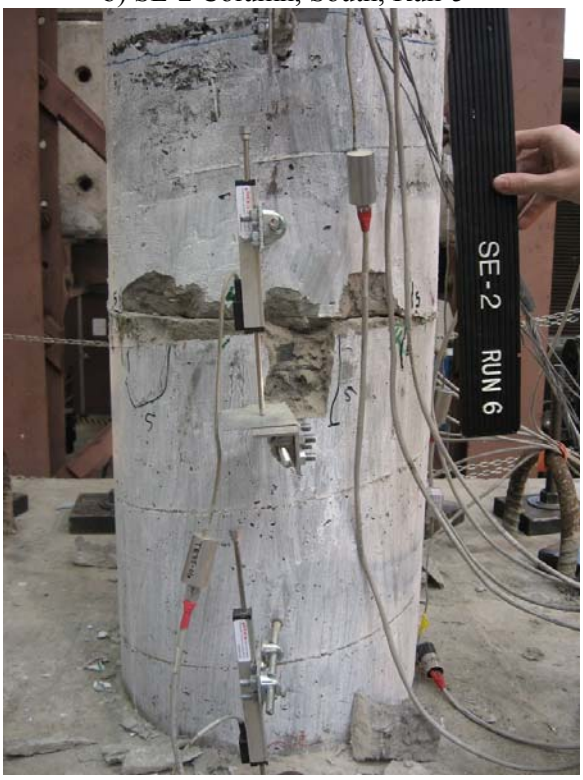
Fig. 3-114. Damage Progression Photographs for SE-2 Column, Bottom, Run 3 and 4

a) SE-2 Column, North, Run-5



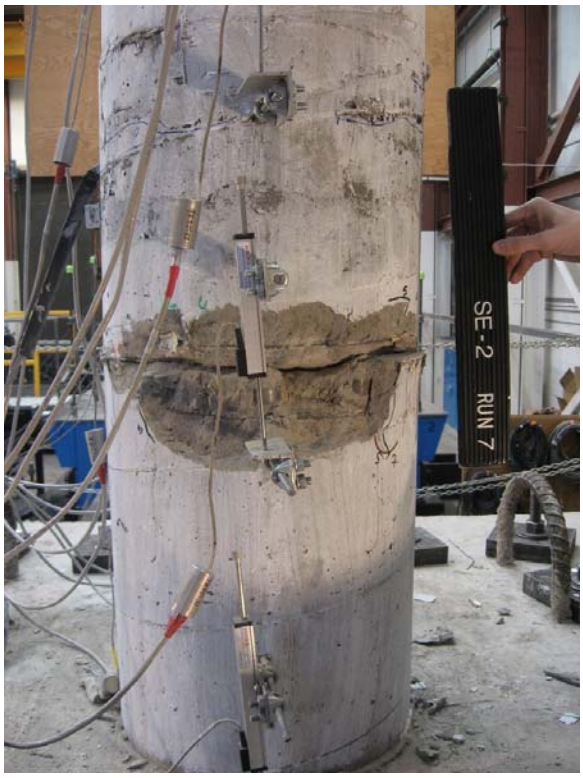
b) SE-2 Column, South, Run-5

c) SE-2 Column, North, Run-6



d) SE-2 Column, South, Run-6

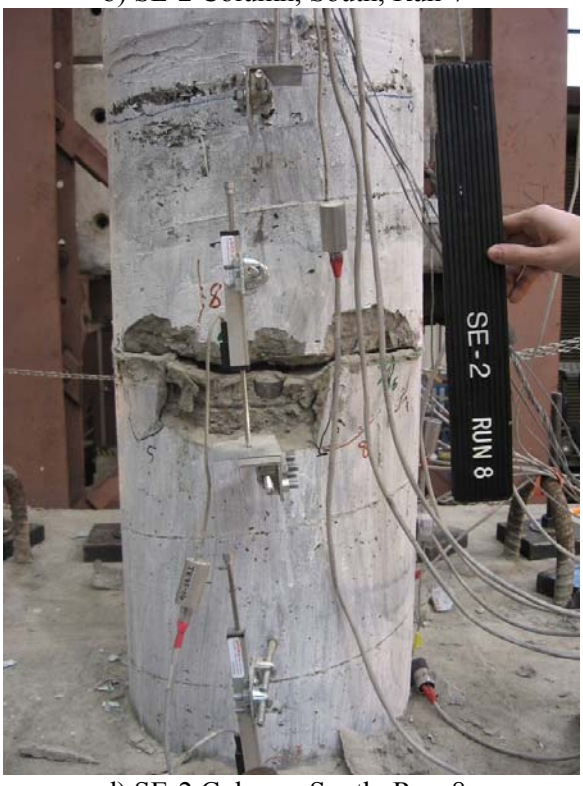
Fig. 3-115. Damage Progression Photographs for SE-2 Column, Bottom, Run 5 and 6



a) SE-2 Column, North, Run-7

b) SE-2 Column, South, Run-7

c) SE-2 Column, North, Run-8



d) SE-2 Column, South, Run-8

Fig. 3-116. Damage Progression Photographs for SE-2 Column, Bottom, Run 7 and 8

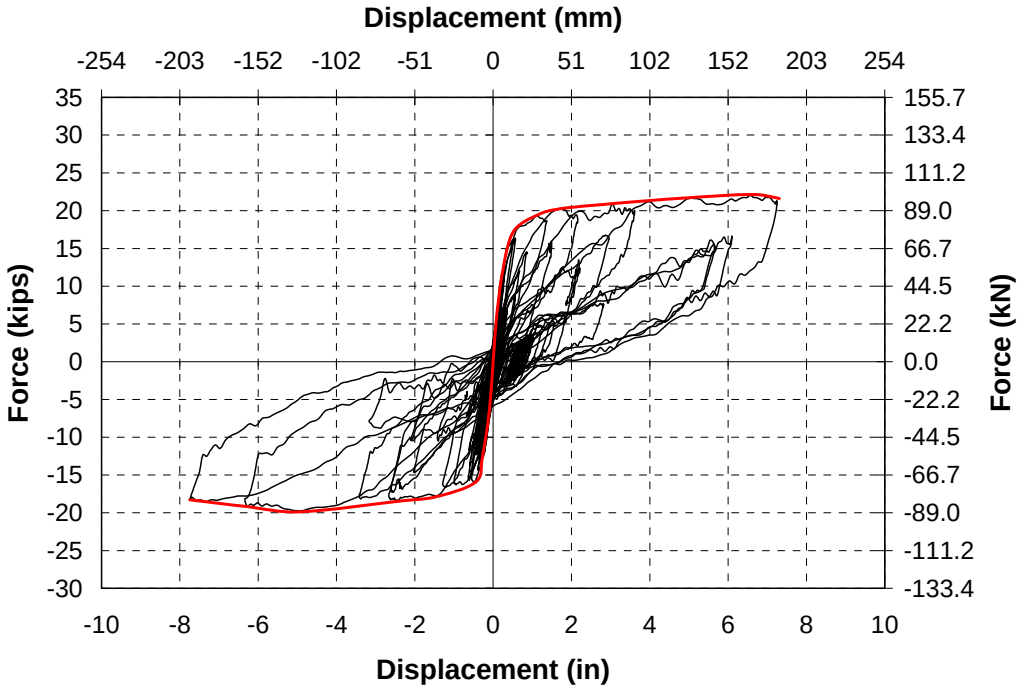


Fig. 3-117. Accumulated Force-Displacement Hysteresis Curve for SE-2

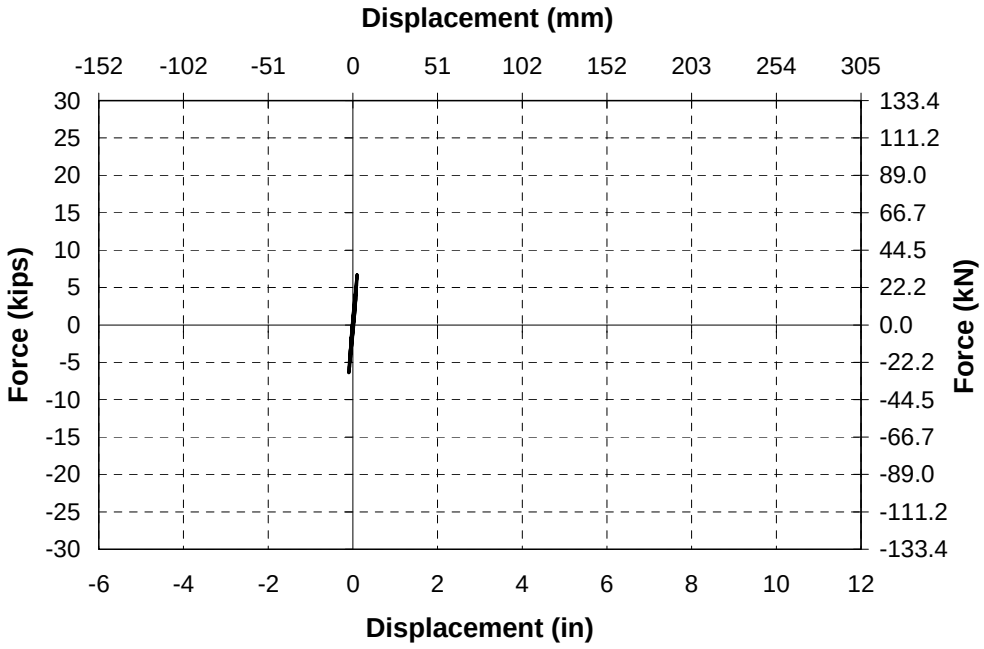


Fig. 3-118. Force-Displacement Hysteresis Curve for Run 1 in SE-2

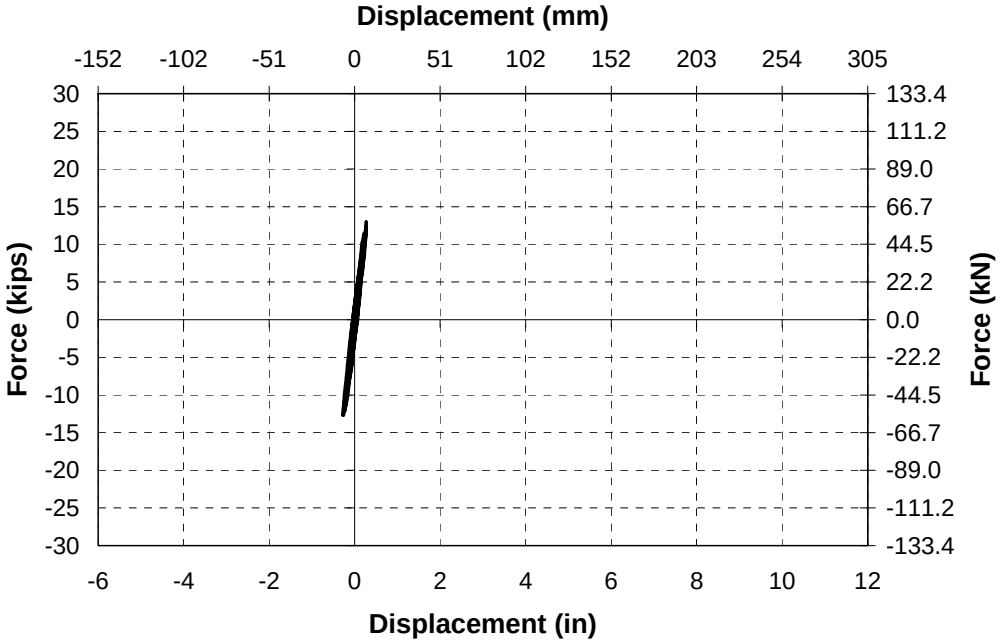


Fig. 3-119. Force-Displacement Hysteresis Curve for Run 2 in SE-2

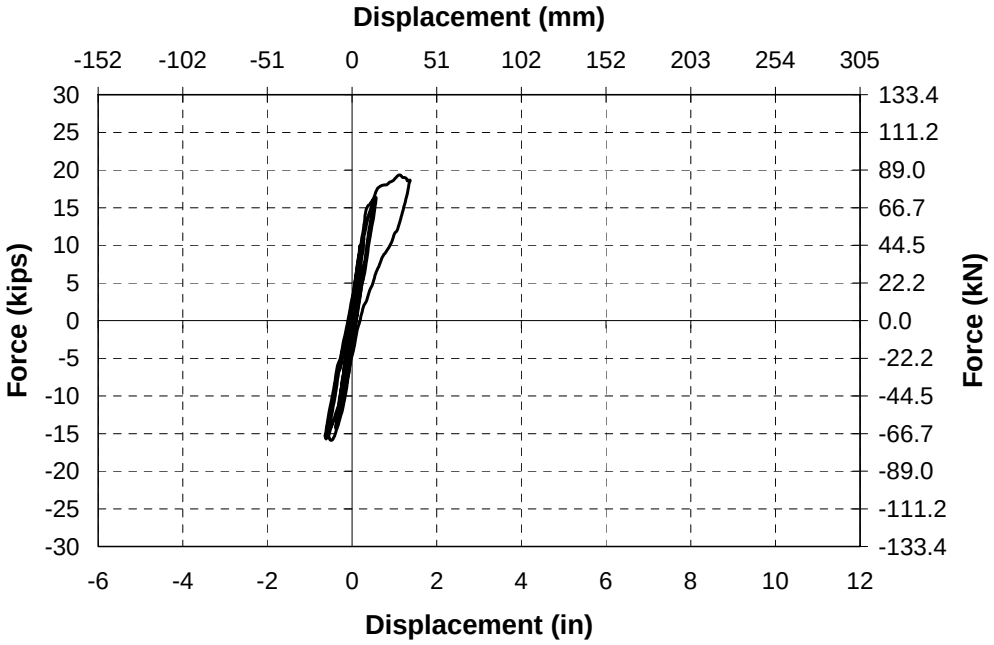


Fig. 3-120. Force-Displacement Hysteresis Curve for Run 3 in SE-2

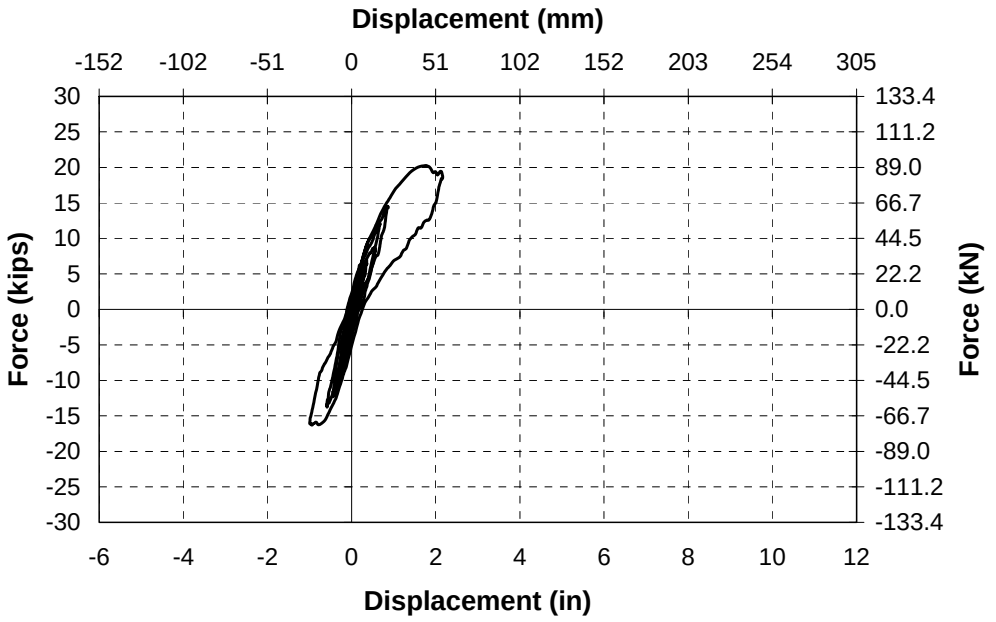


Fig. 3-121. Force-Displacement Hysteresis Curve for Run 4 in SE-2

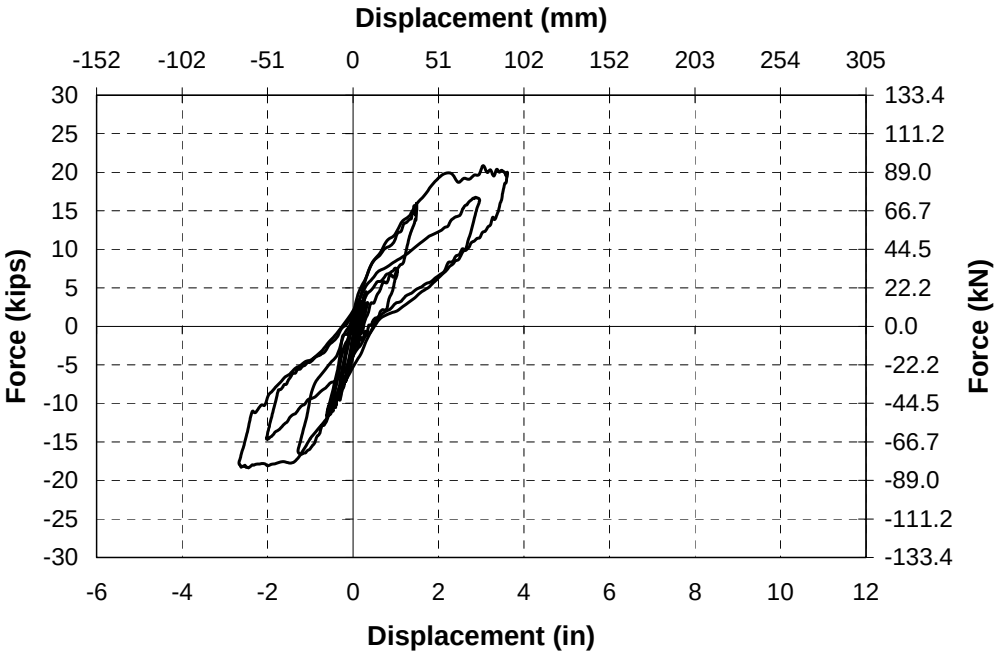


Fig. 3-122. Force-Displacement Hysteresis Curve for Run 5 in SE-2

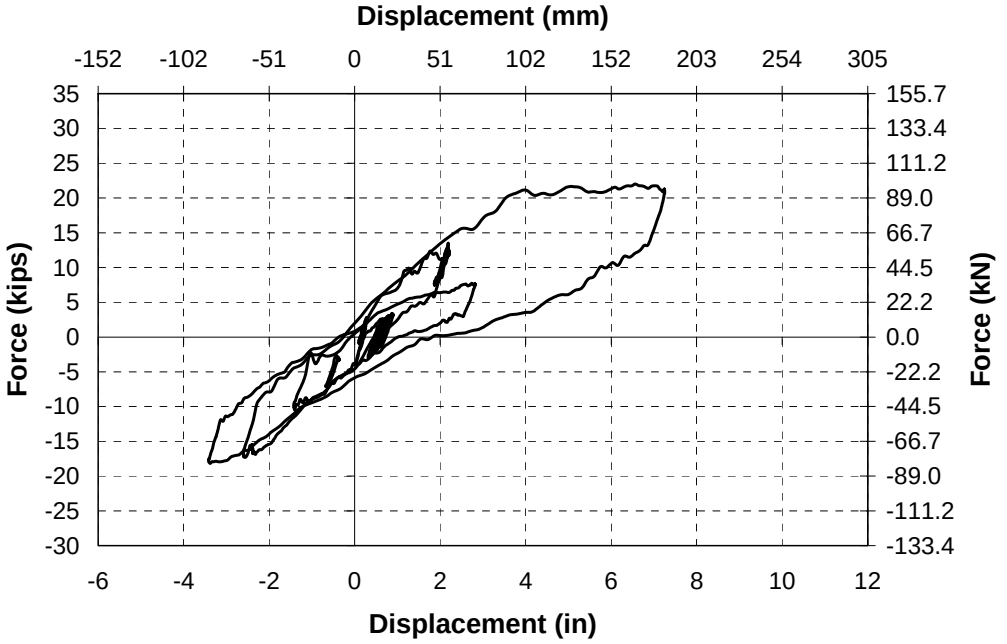


Fig. 3-123. Force-Displacement Hysteresis Curve for Run 6 in SE-2

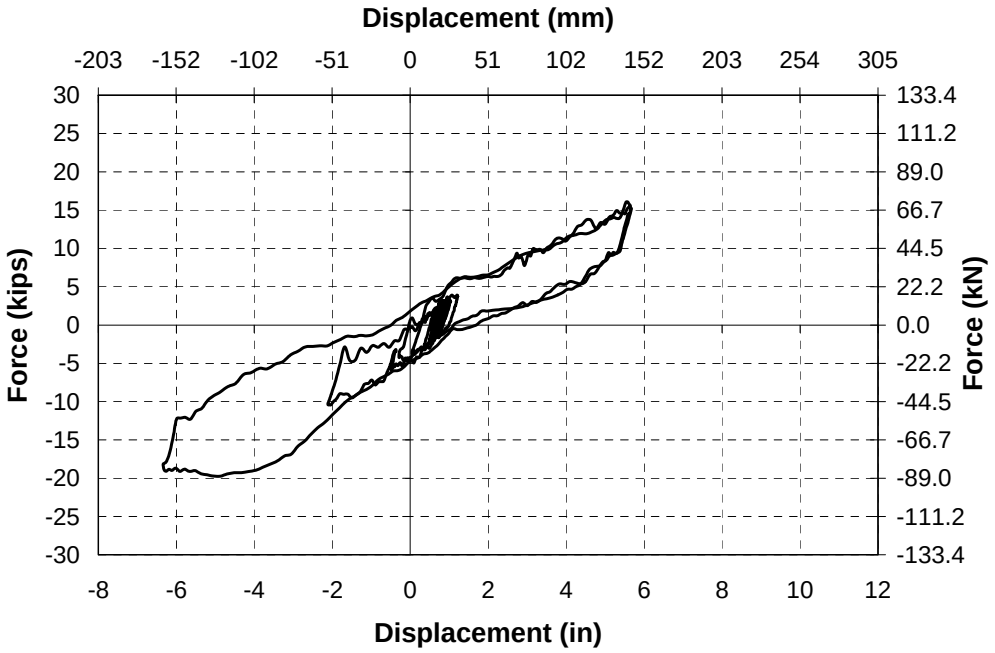


Fig. 3-124. Force-Displacement Hysteresis Curve for Run 7 in SE-2

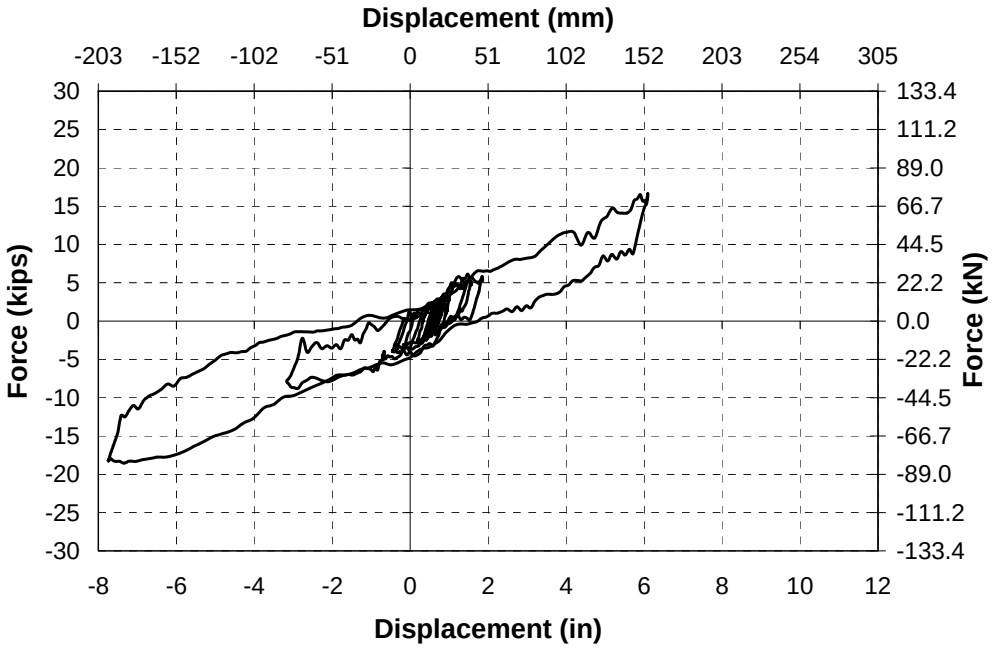


Fig. 3-125. Force-Displacement Hysteresis Curve for Run 8 in SE-2

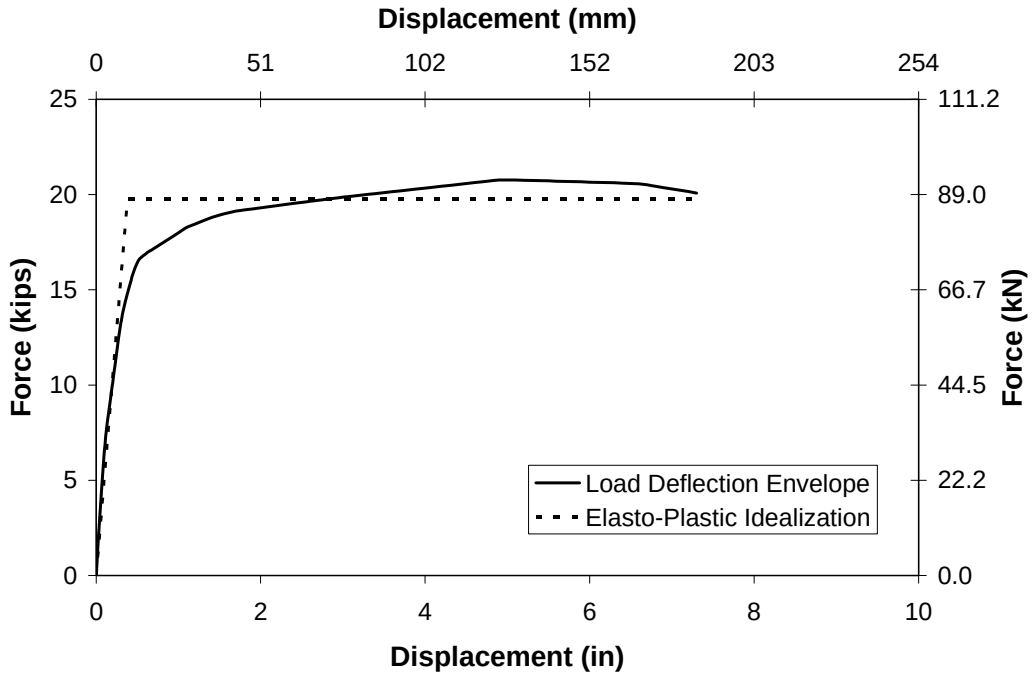


Fig. 3-126. Backbone Curve of SE-2

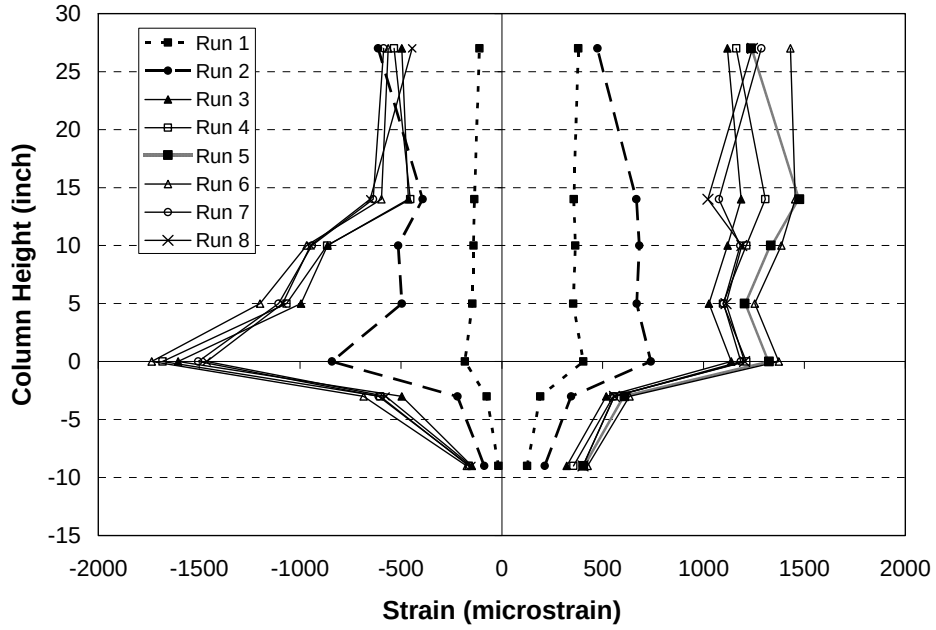


Fig. 3-127. The Max. and Min. Long. Strain Profile of the SE-2

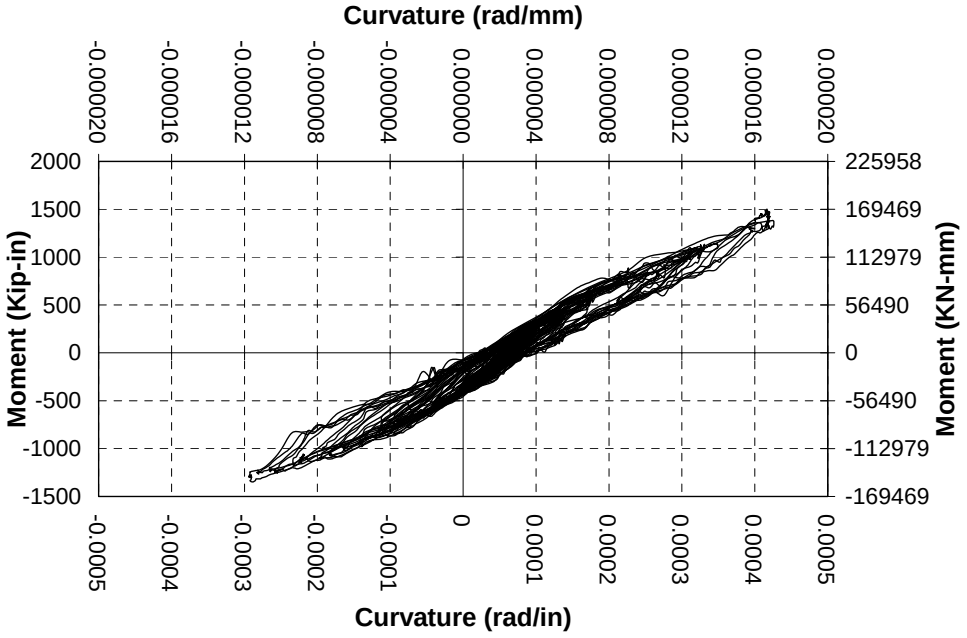


Fig. 3-128. Accumulated Moment Curvature at the First Level in SE-2

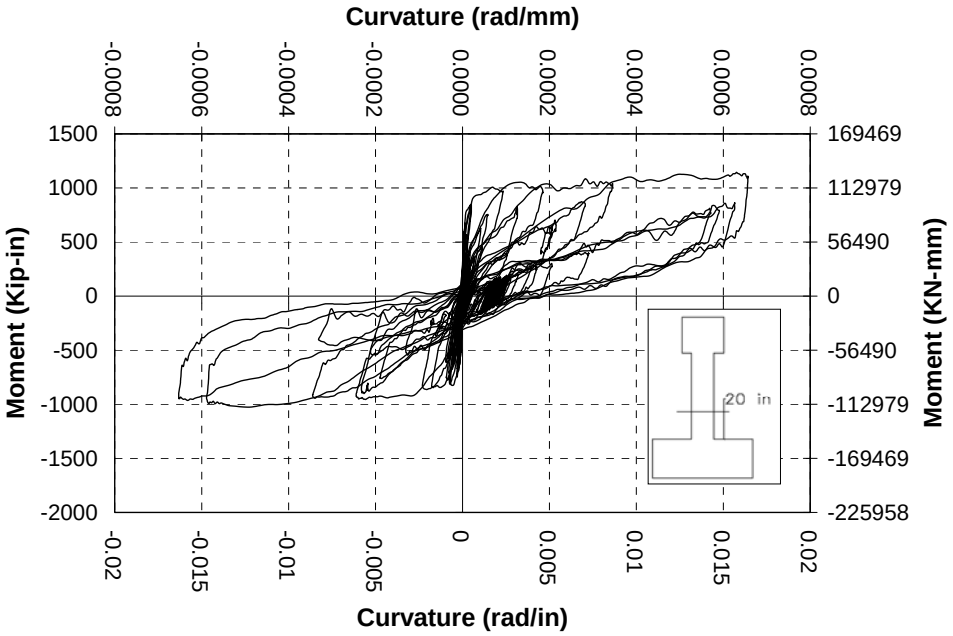


Fig. 3-129. Accumulated Moment Curvature at the Second Level in SE-2

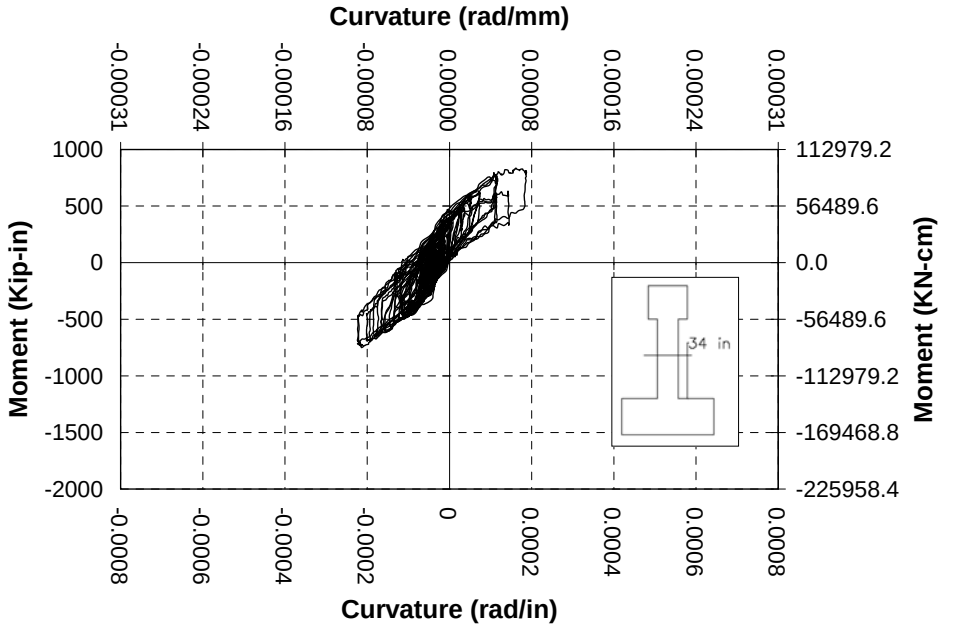


Fig. 3-130. Accumulated Moment Curvature at the Third Level in SE-2

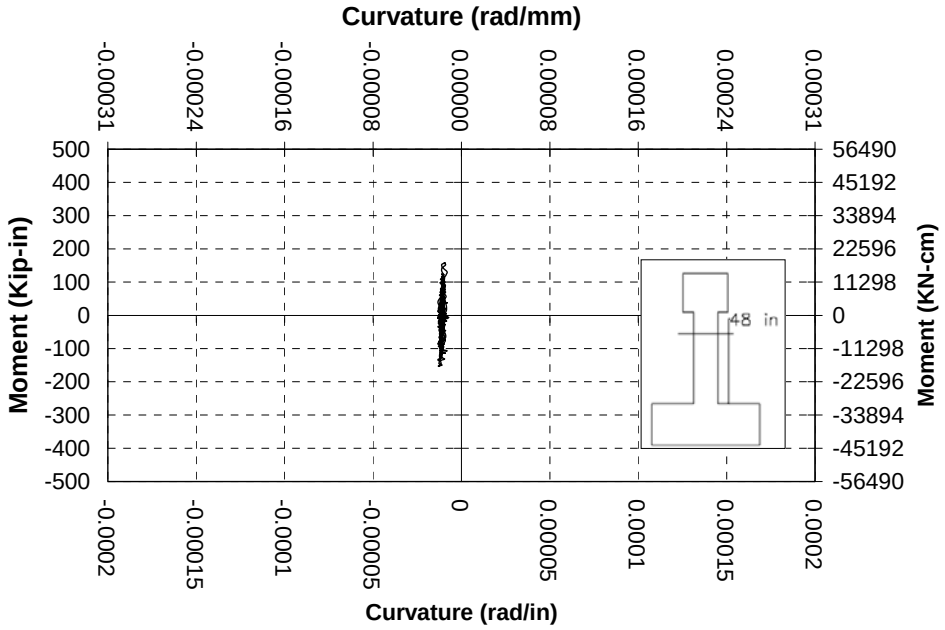


Fig. 3-131. Accumulated Moment Curvature at the Fourth Level in SE-2

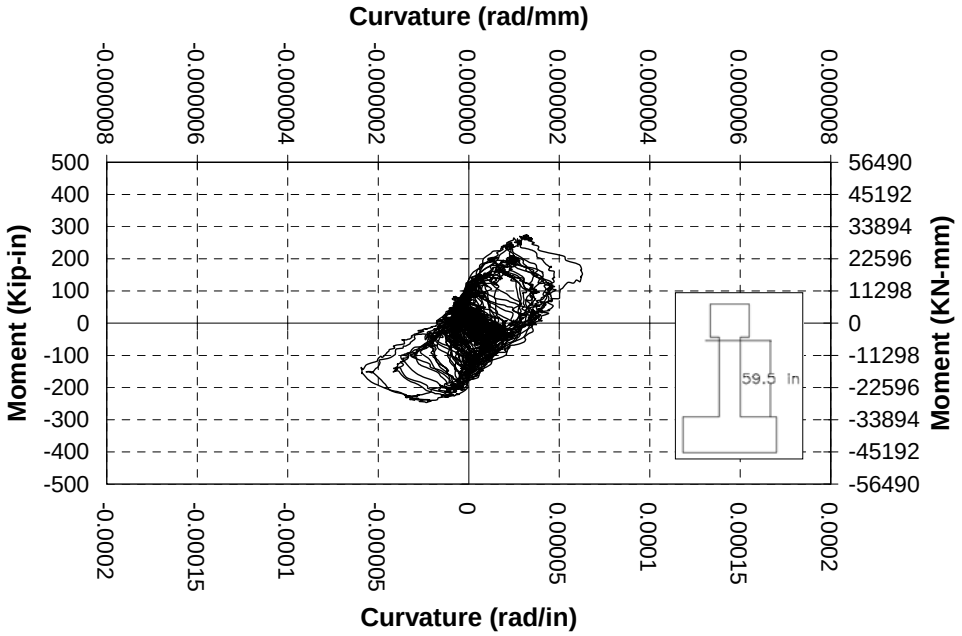


Fig. 3-132. Accumulated Moment Curvature at the Fifth Level in SE-2

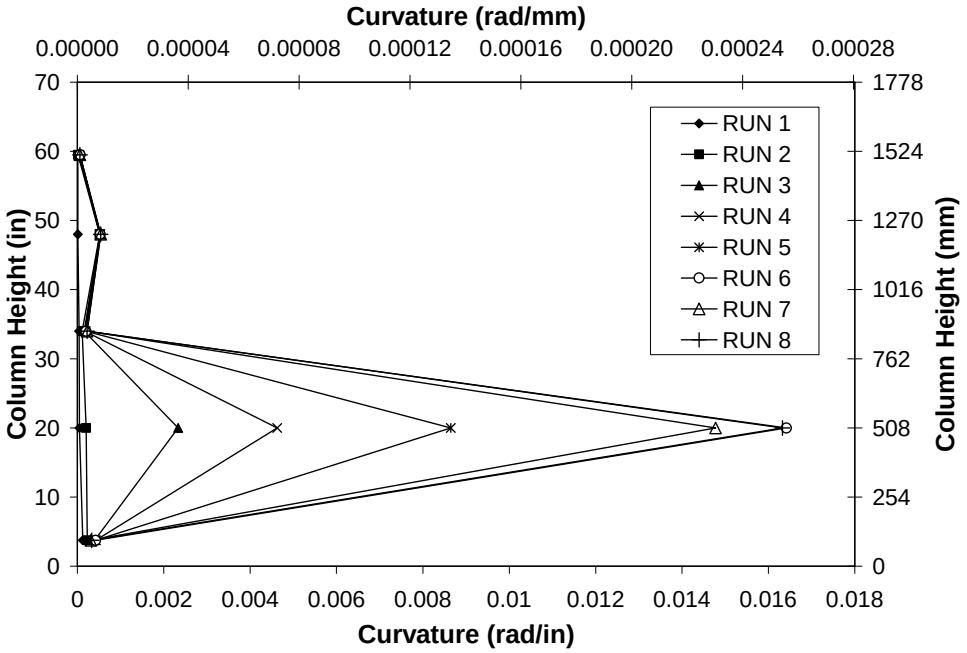


Fig. 3-133. Curvature Profile for SE-2

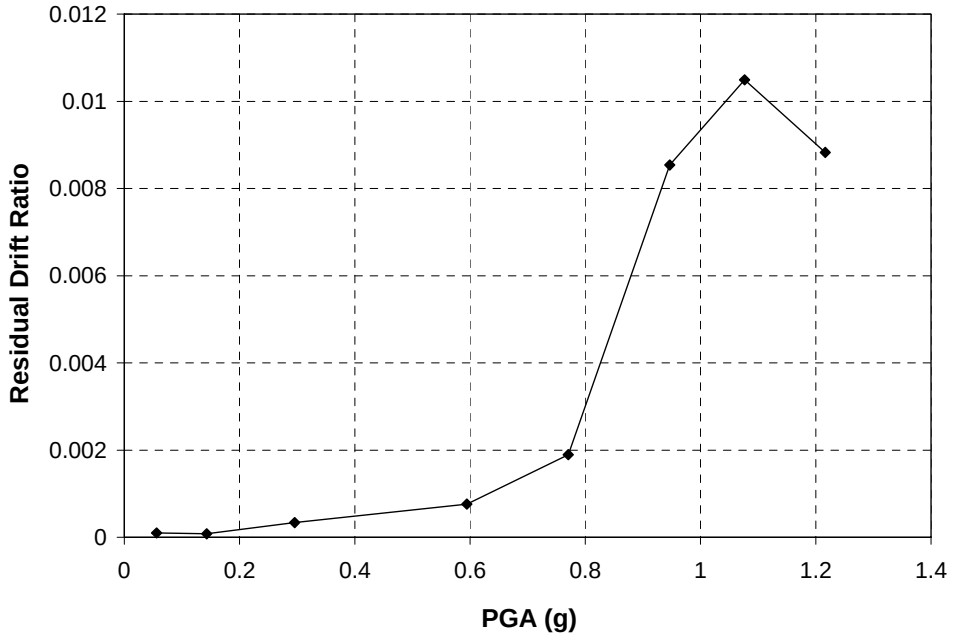


Fig. 3-134. Residual Drift Ratio vs. PGA in SE-2

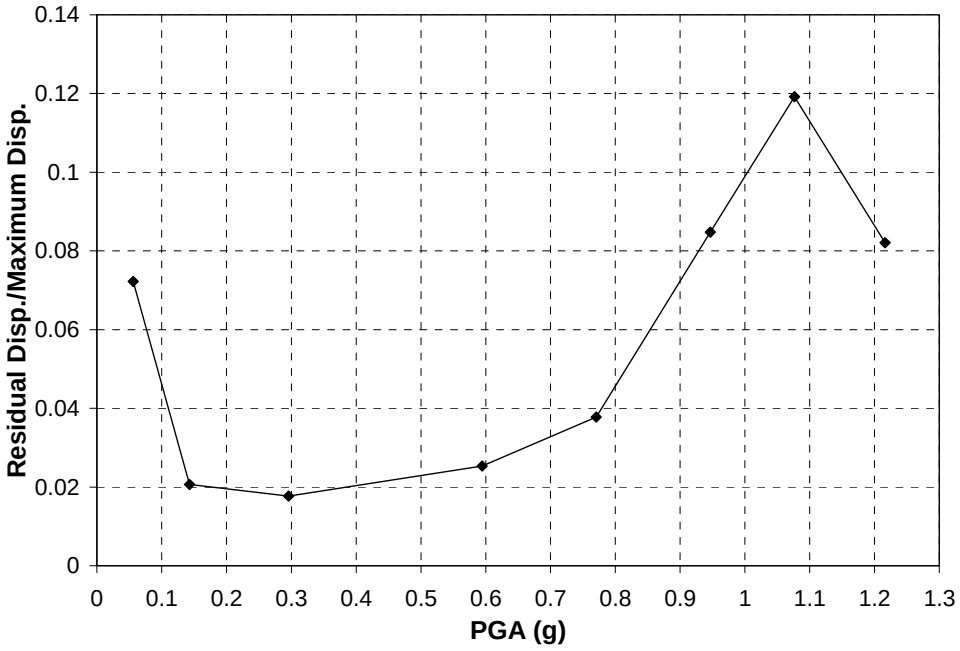


Fig. 3-135. Residual Disp. / Max. Disp. vs. PGA in SE-2

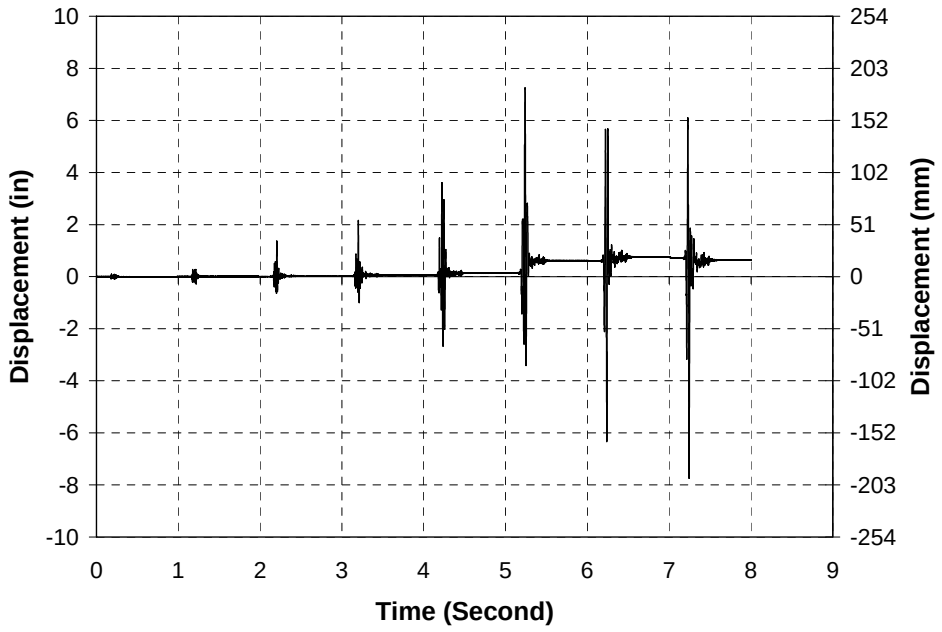


Fig. 3-136. Displacement History in Column SE-2

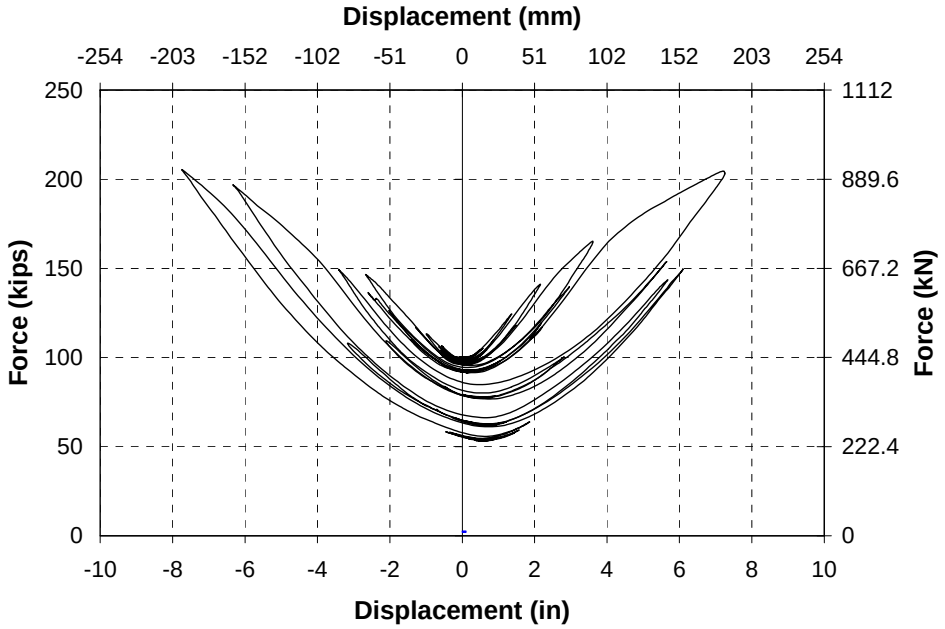


Fig. 3-137. Unbonded PT Rod Force vs. Displacement in SE-2

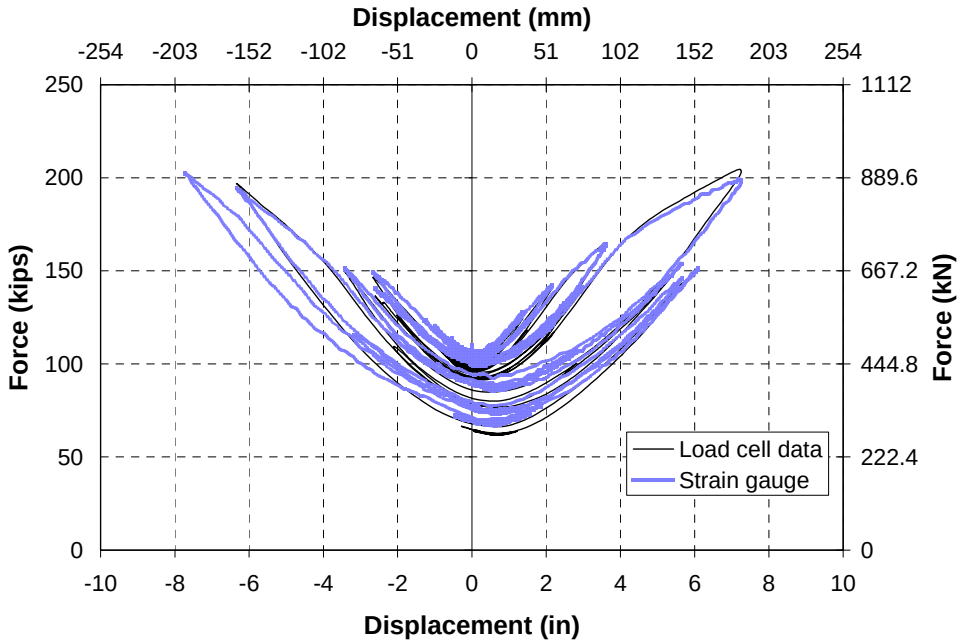


Fig. 3-138. Comparison of Unbonded PT Rod Force Measured by Load Cell and Strain Gauges in SE-2

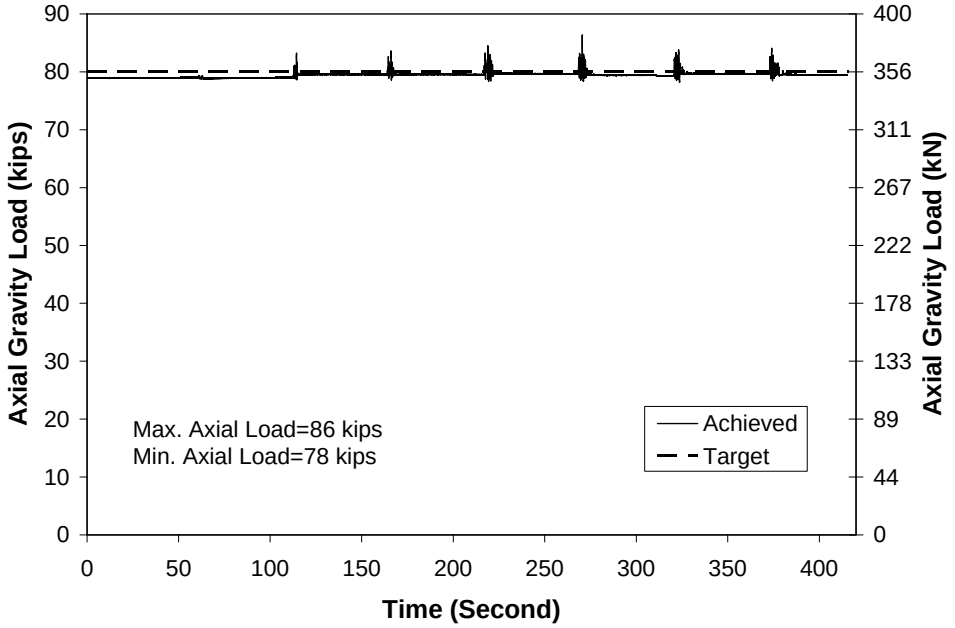


Fig. 3-139. Axial Gravity Load History on SE-2

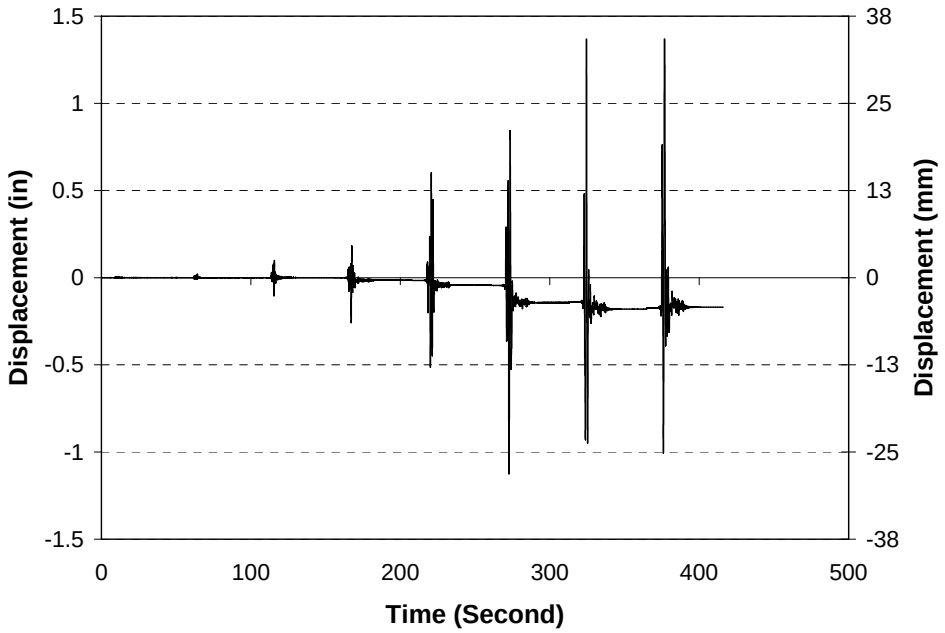


Fig. 3-140. History of Segment Separation at North Side of the SE-2

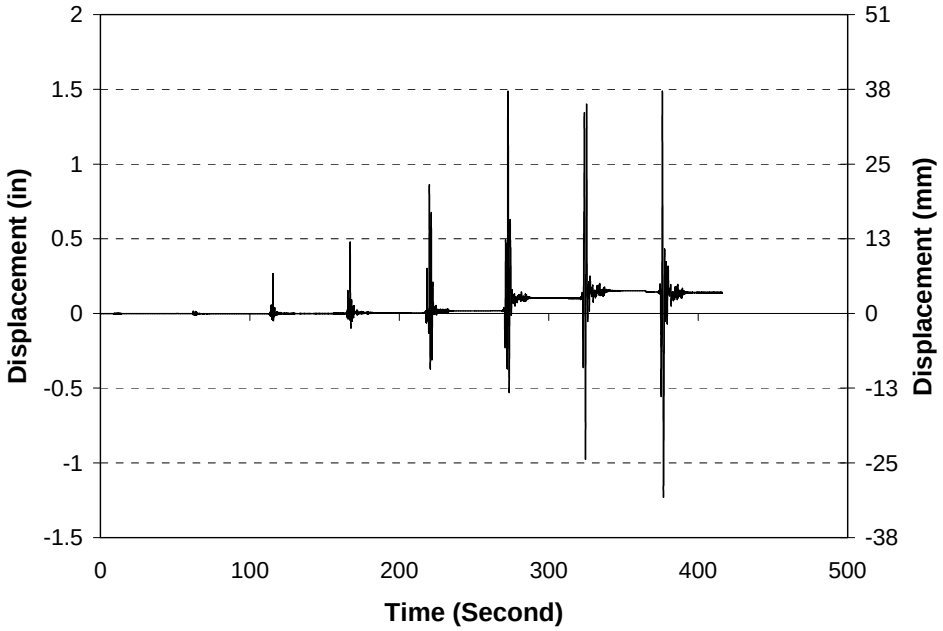


Fig. 3-141. History of Segment Separation at South Side of the SE-2

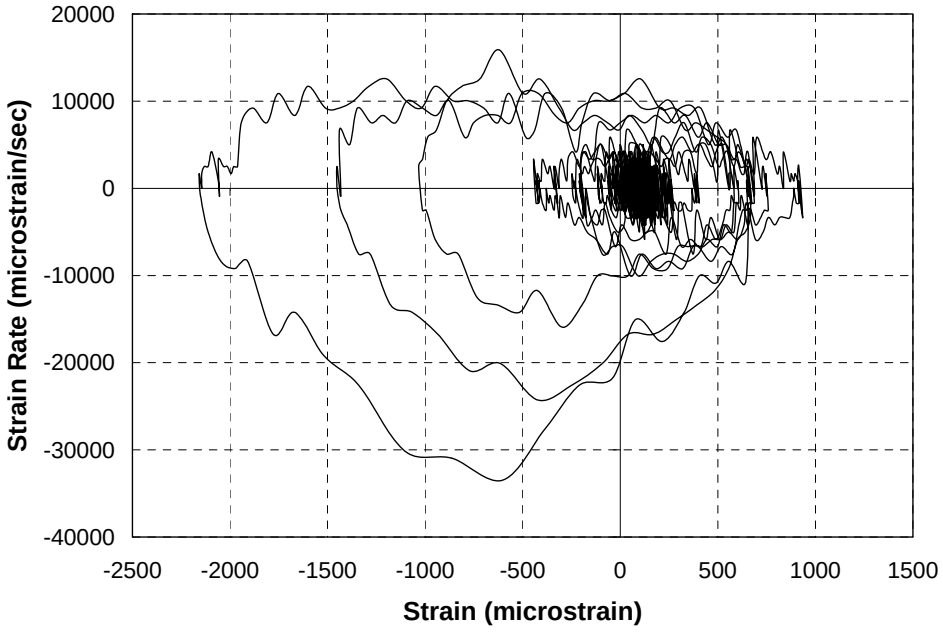


Fig. 3-142. Strain Rate vs. Strain in SE-2, Gauge 13, Run 4

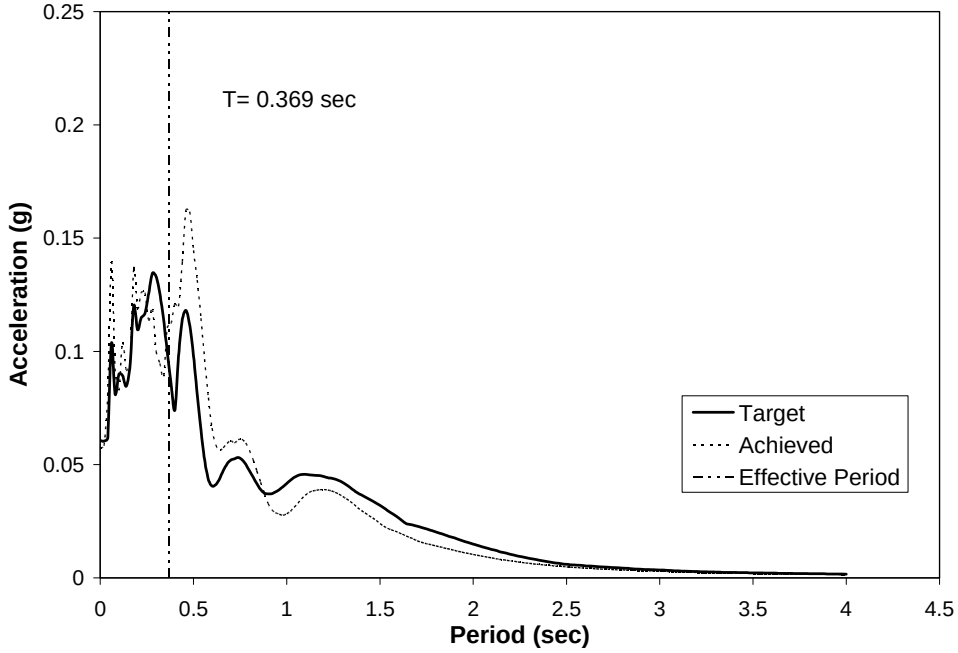


Fig. 3-143. Target vs. Achieved Ground Motion Spectra, Run-1 in SE-2

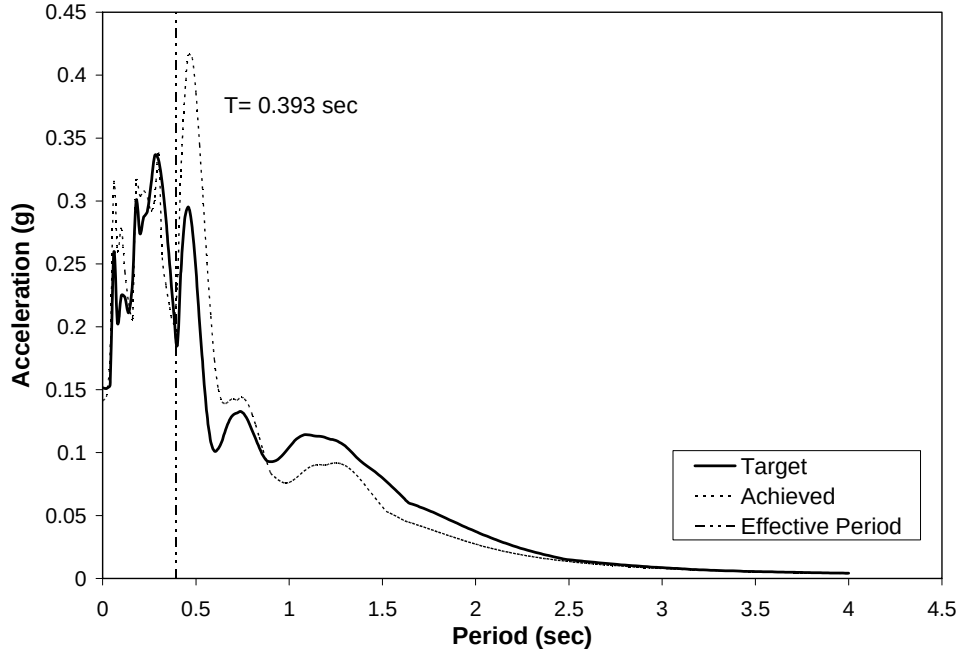


Fig. 3-144. Target vs. Achieved Ground Motion Spectra, Run-2 in SE-2

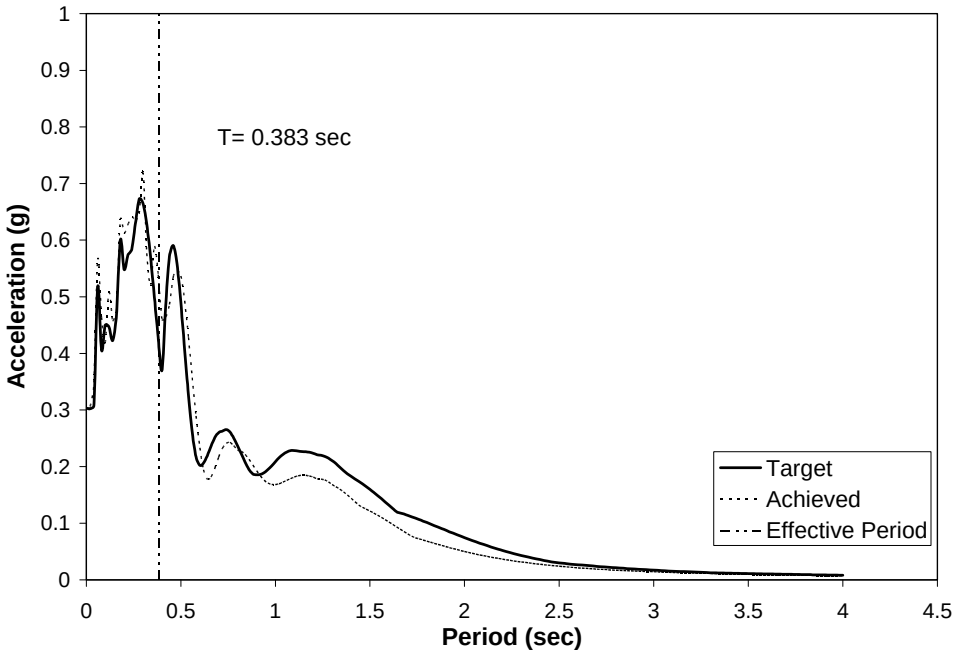


Fig. 3-145. Target vs. Achieved Ground Motion Spectra, Run-3 in SE-2

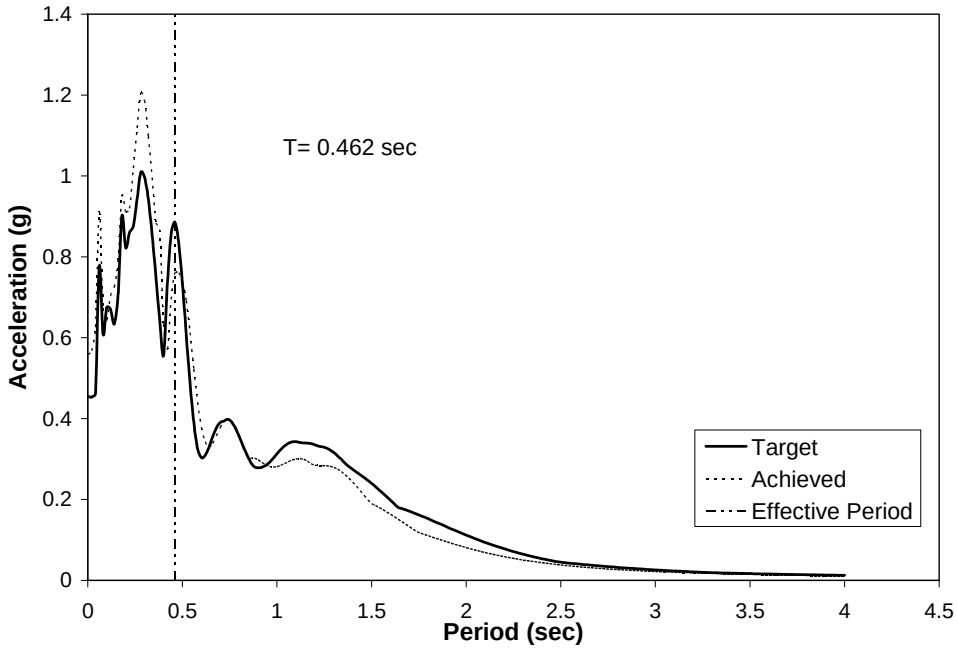


Fig. 3-146. Target vs. Achieved Ground Motion Spectra, Run-4 in SE-2

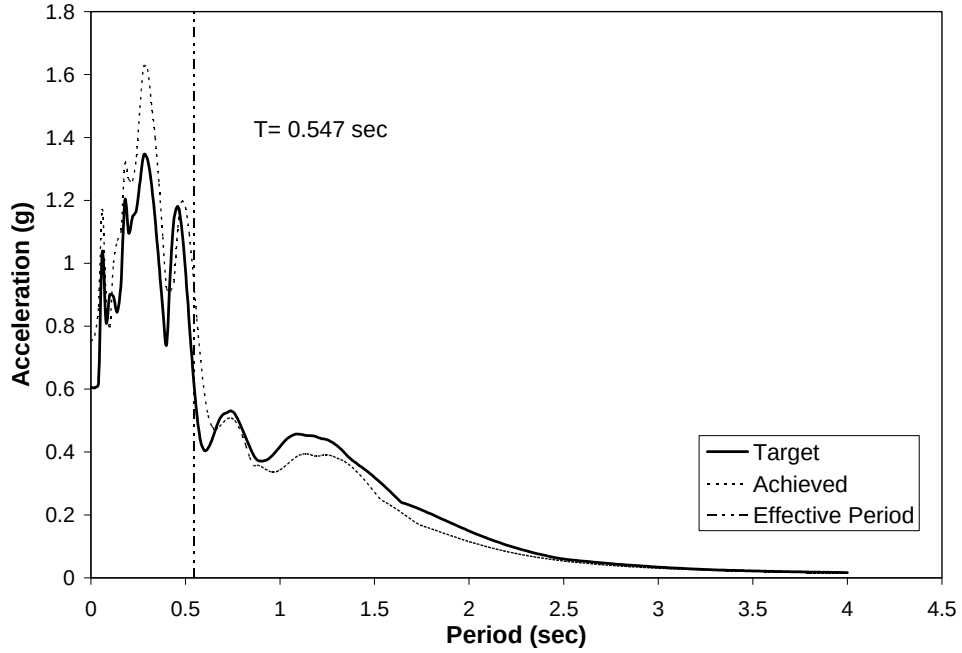


Fig. 3-147. Target vs. Achieved Ground Motion Spectra, Run-5 in SE-2

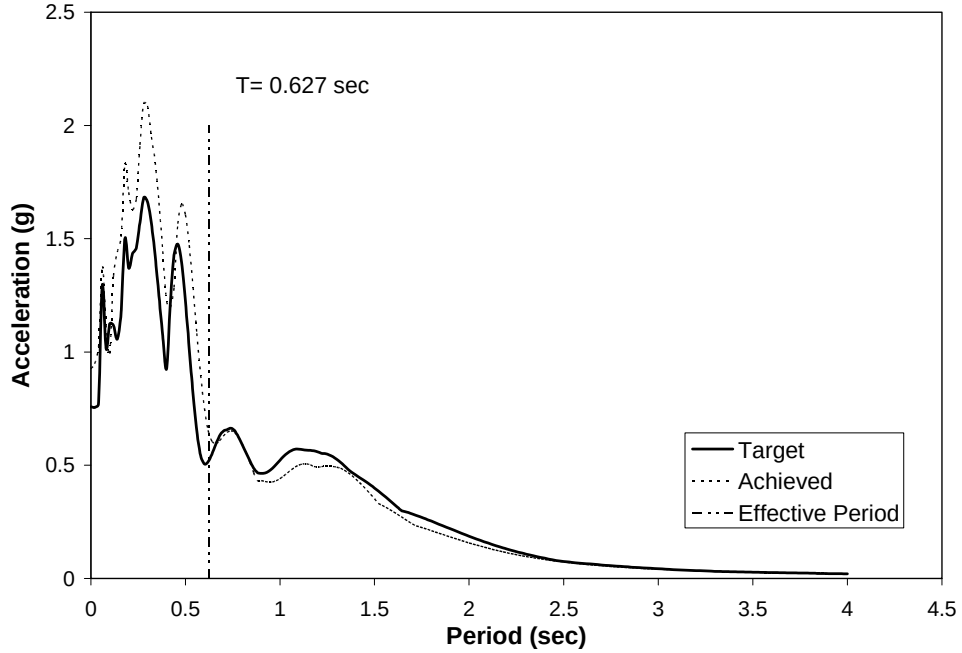


Fig. 3-148. Target vs. Achieved Ground Motion Spectra, Run-6 in SE-2

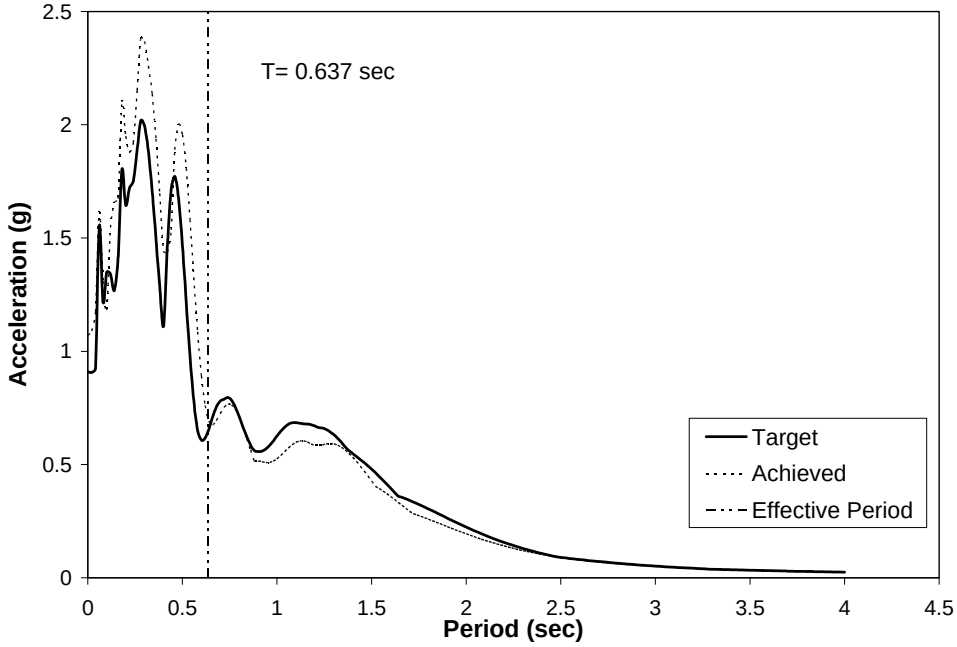


Fig. 3-149. Target vs. Achieved Ground Motion Spectra, Run-7 in SE-2

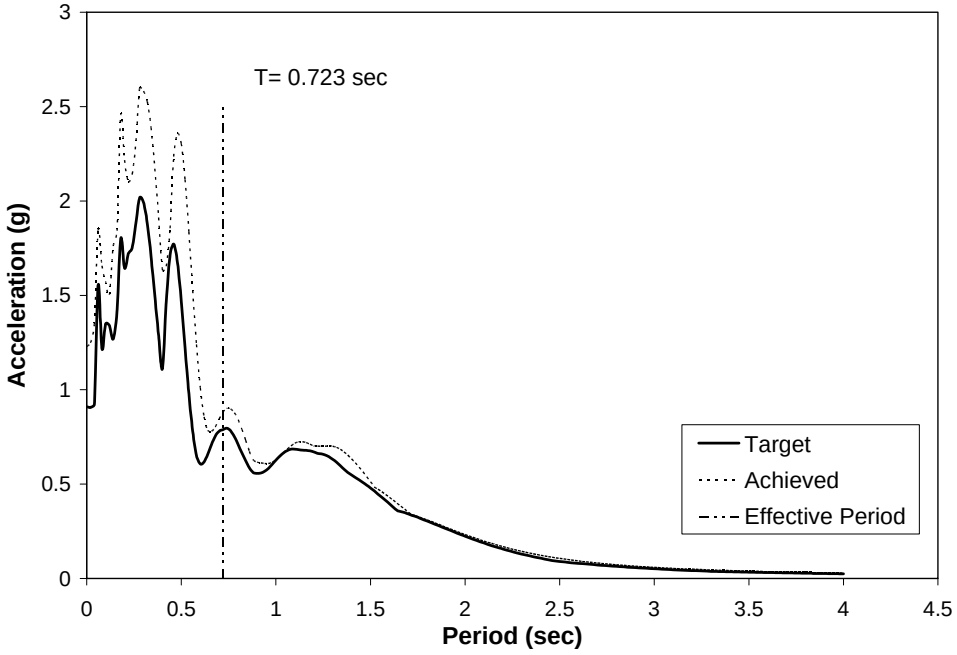
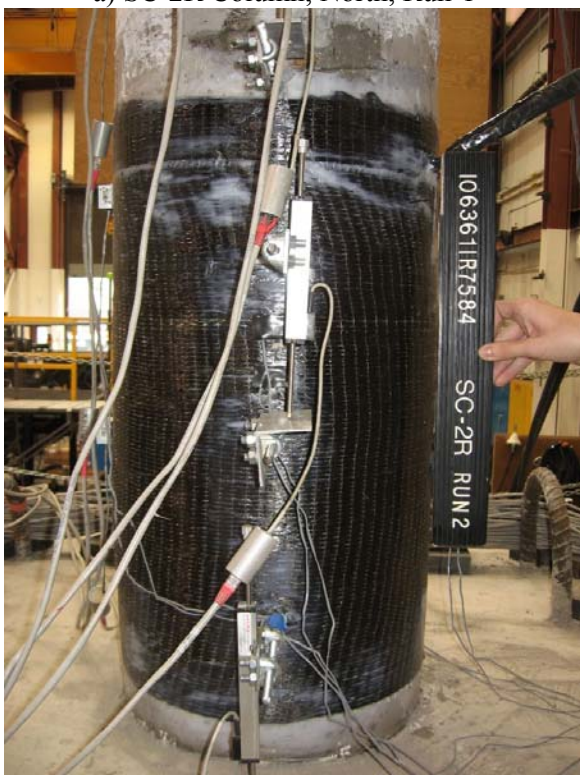


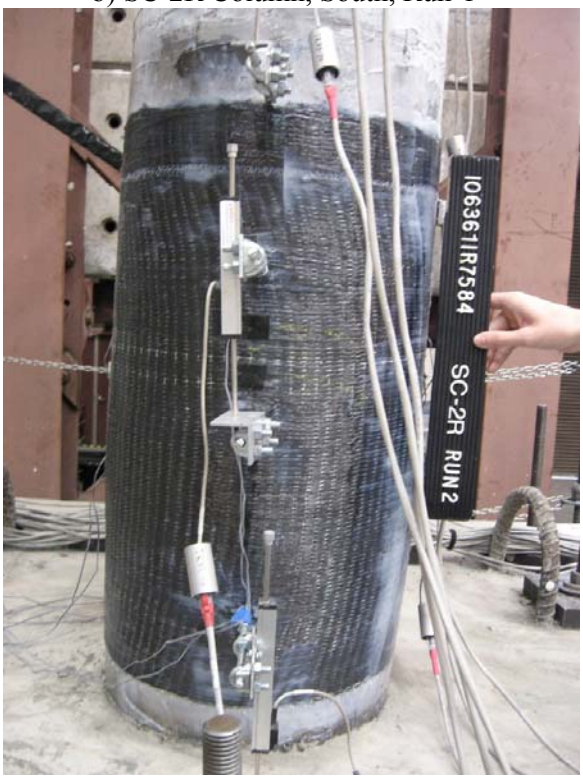
Fig. 3-150. Target vs. Achieved Ground Motion Spectra, Run-8 in SE-2

a) SC-2R Column, North, Run-1

b) SC-2R Column, South, Run-1

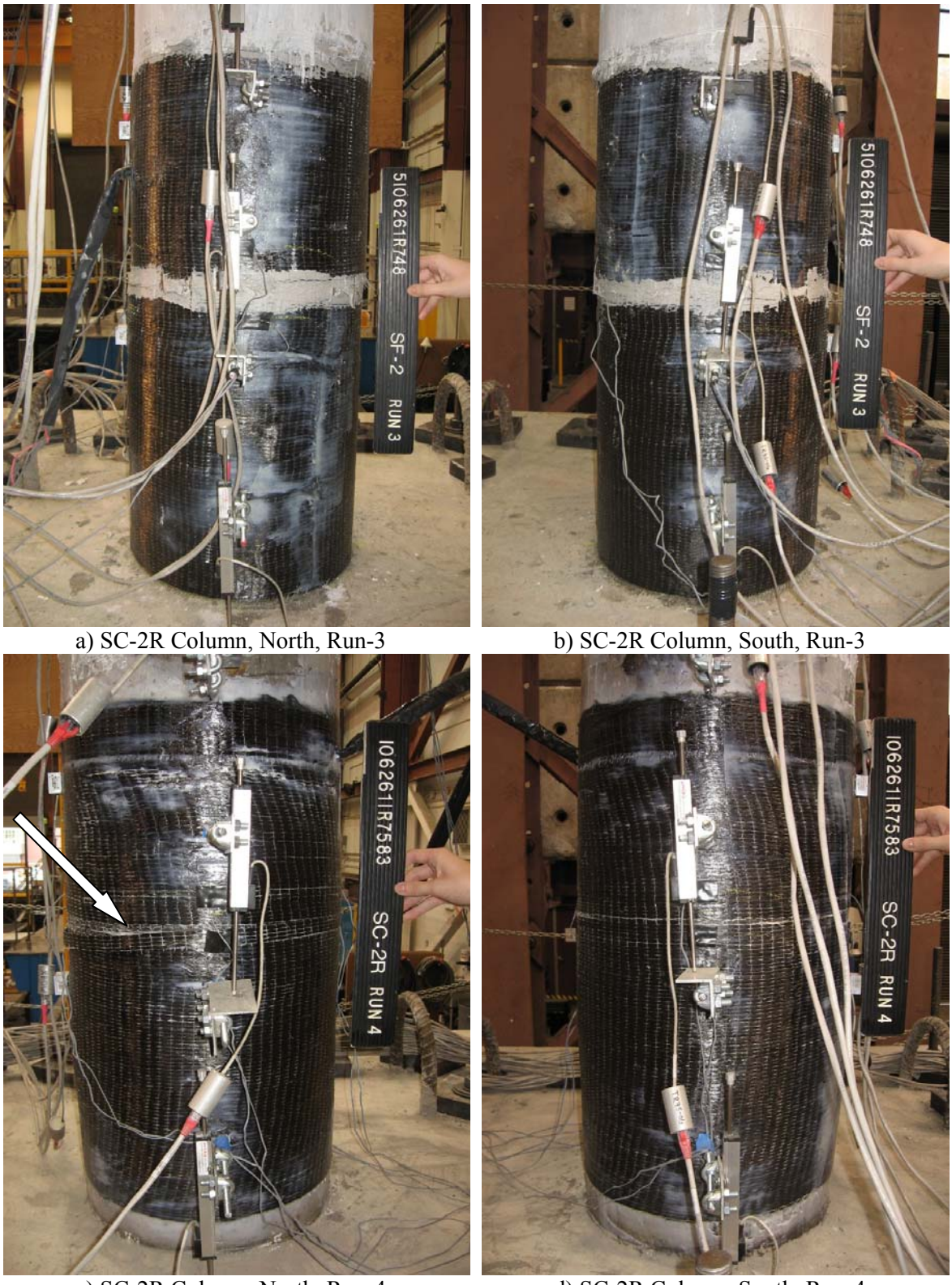


c) SC-2R Column, North, Run-2



d) SC-2R Column, South, Run-2

Fig. 3-151. Damage Progression Photographs for SE-2 Column, Bottom, Run 1 and 2



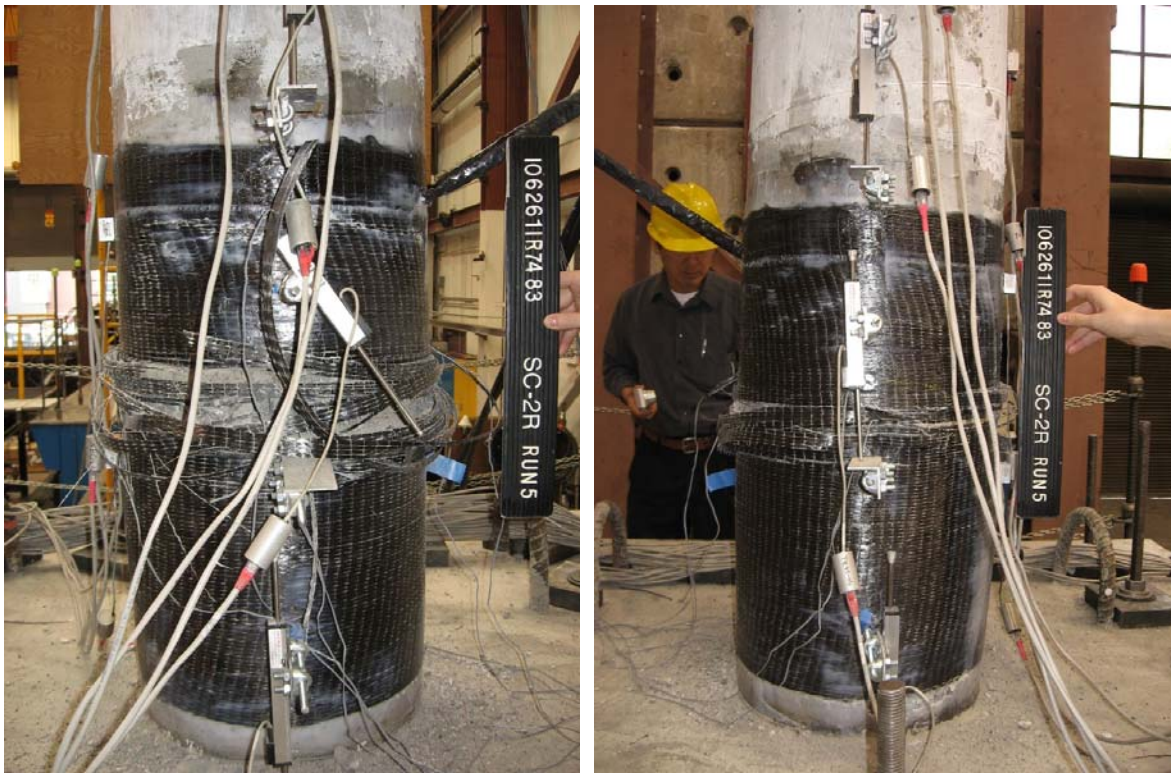
a) SC-2R Column, North, Run-3

b) SC-2R Column, South, Run-3

c) SC-2R Column, North, Run-4

d) SC-2R Column, South, Run-4

Fig. 3-152. Damage Progression Photographs for SE-2 Column, Bottom, Run 3 and 4



a) SC-2R Column, North, Run-5 b) SC-2R Column, South, Run-5

Fig. 3-153. Damage Progression Photographs for SC-2R Column, Bottom, Run 5

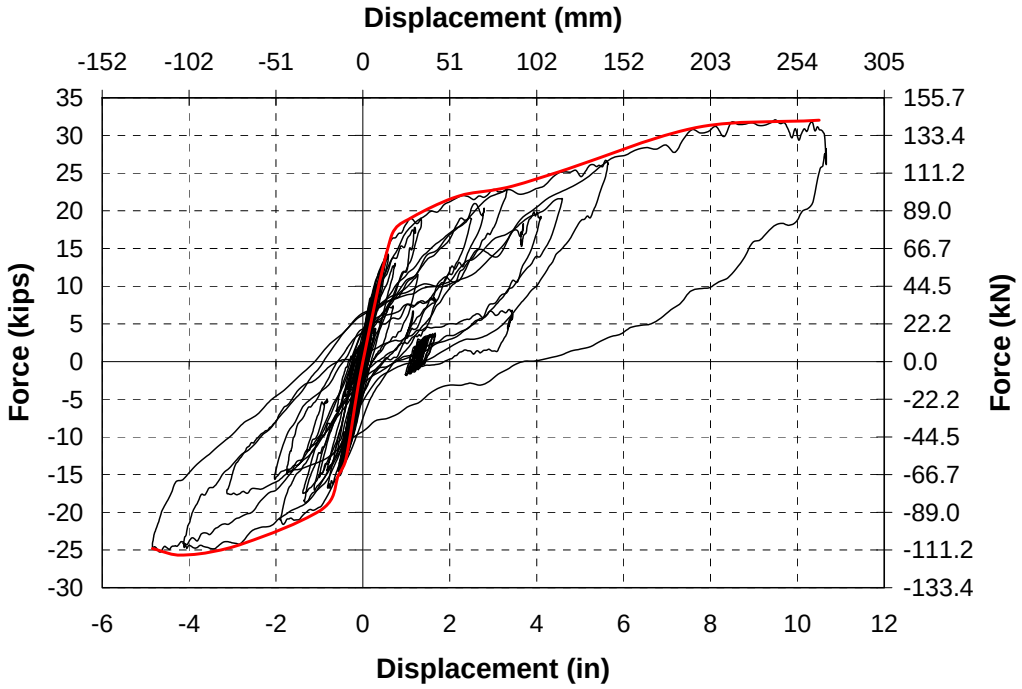


Fig. 3-154. Accumulated Force-Displacement Hysteresis Curve for SC-2R

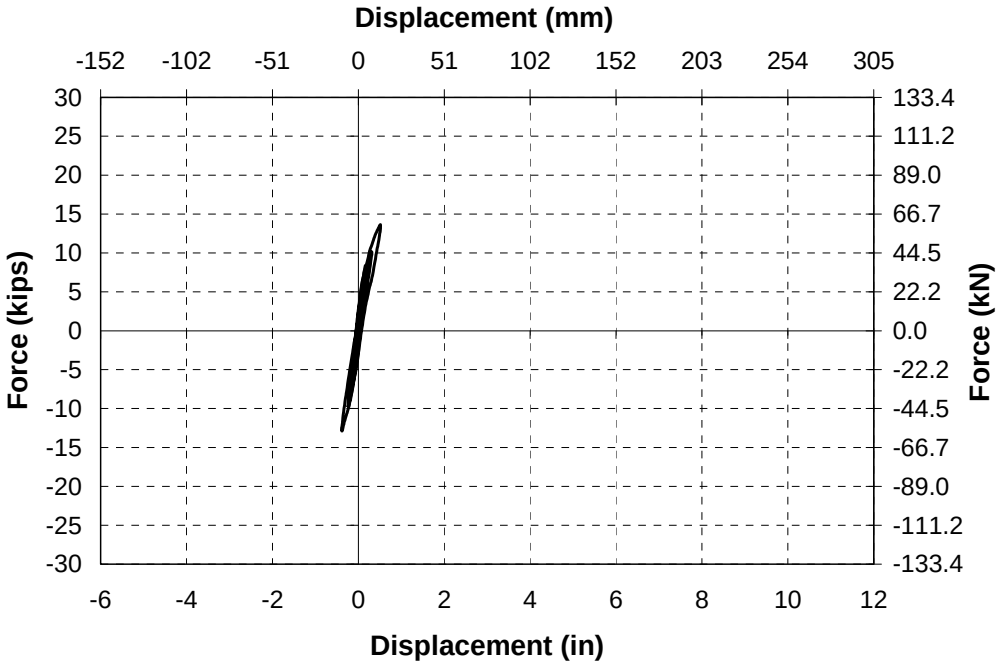


Fig. 3-155. Force-Displacement Hysteresis Curve for Run 1 in SC-2R

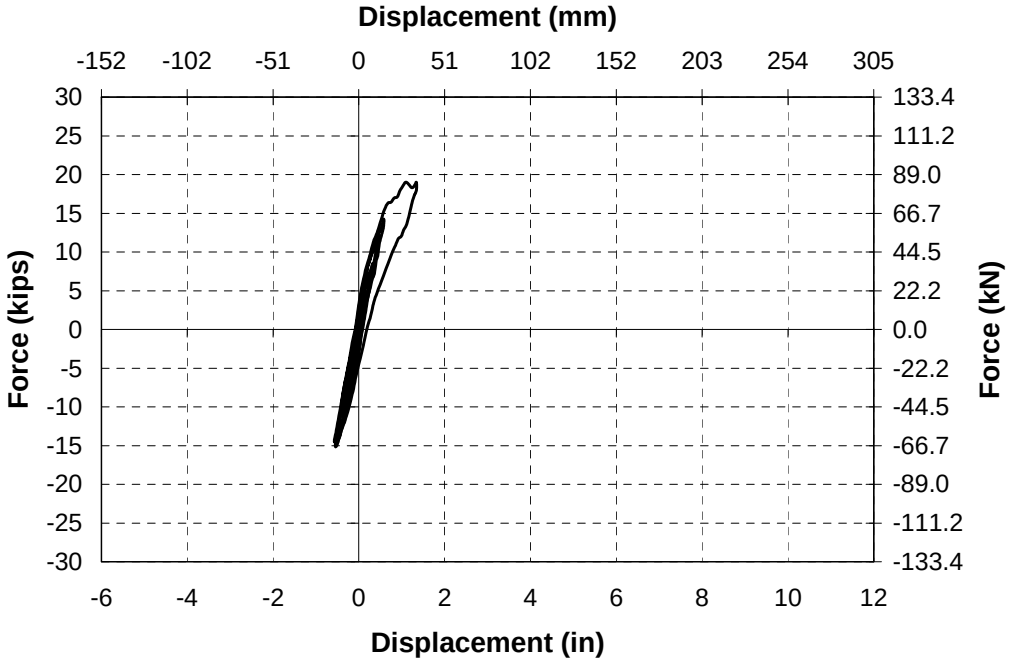


Fig. 3-156. Force-Displacement Hysteresis Curve for Run 2 in SC-2R

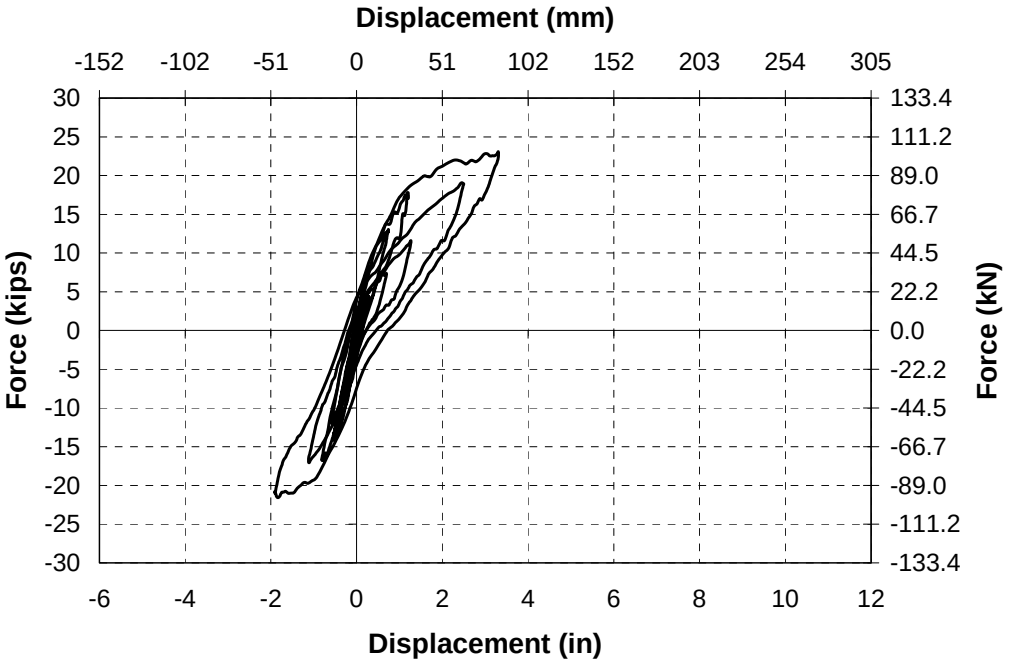


Fig. 3-157. Force-Displacement Hysteresis Curve for Run 3 in SC-2R

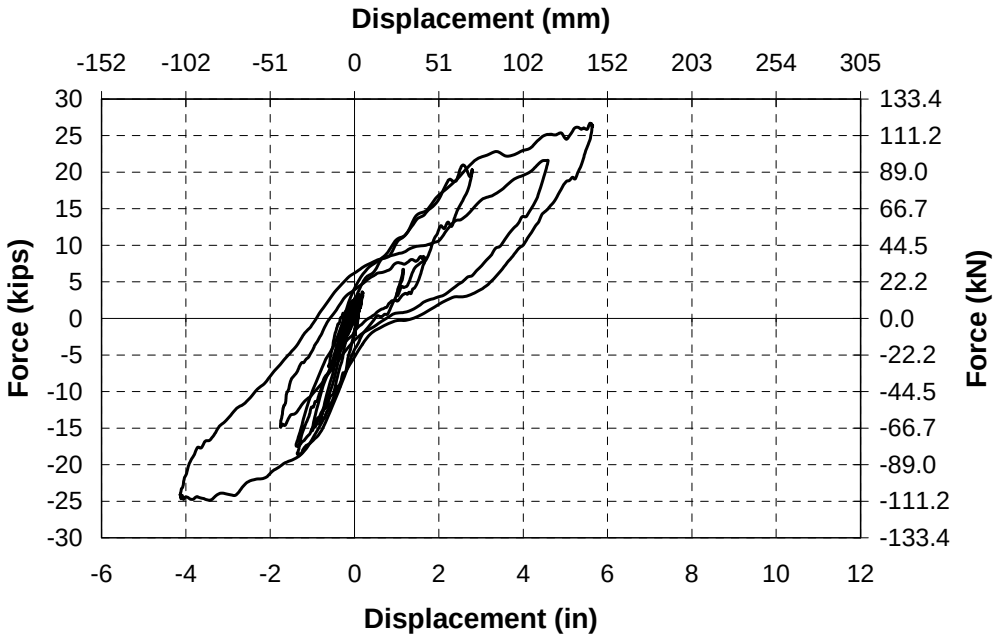


Fig. 3-158. Force-Displacement Hysteresis Curve for Run 4 in SC-2R

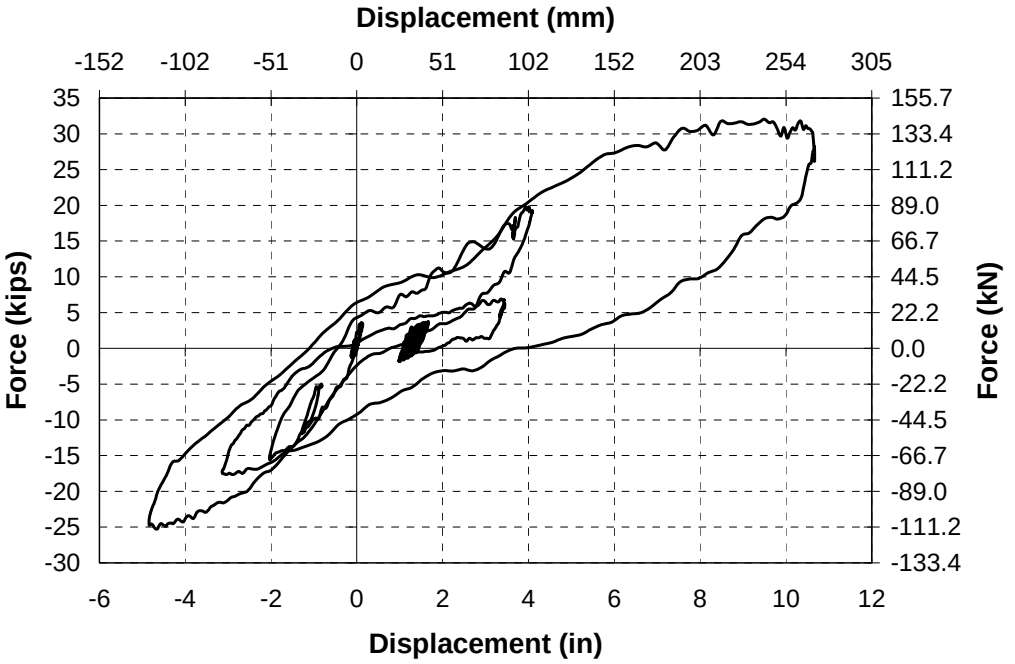


Fig. 3-159. Force-Displacement Hysteresis Curve for Run 5 in SC-2R

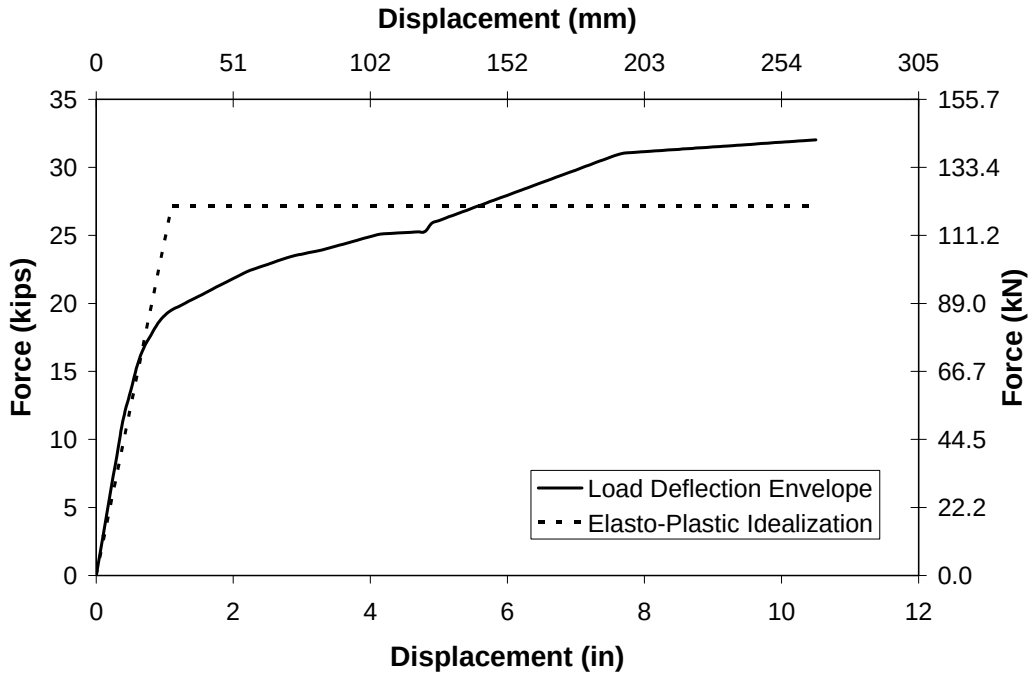


Fig. 3-160. Backbone Curve of SC-2R

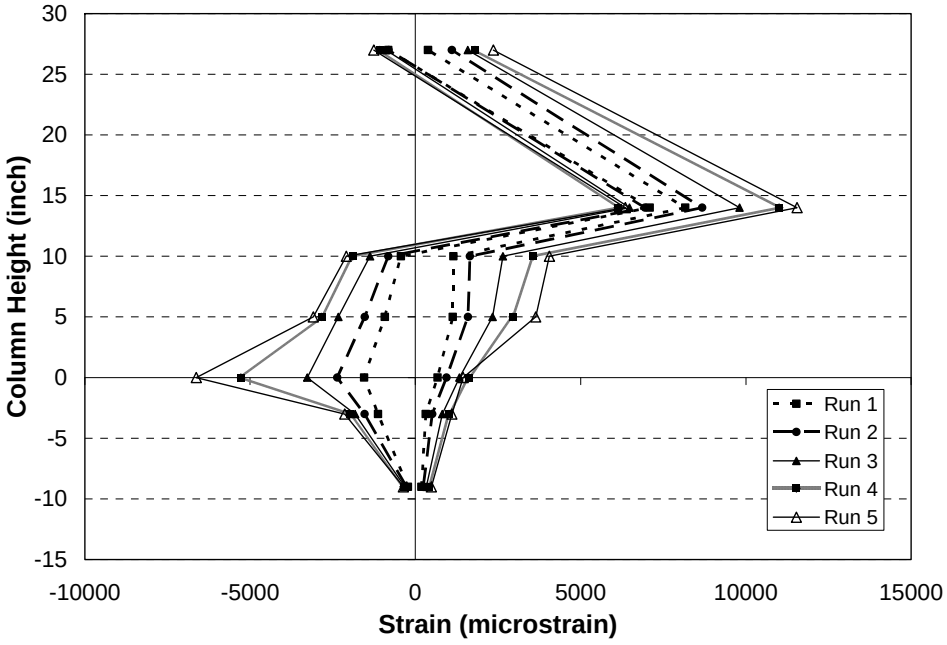


Fig. 3-161. The Max. and Min. Long. Strain Profile of the SC-2R

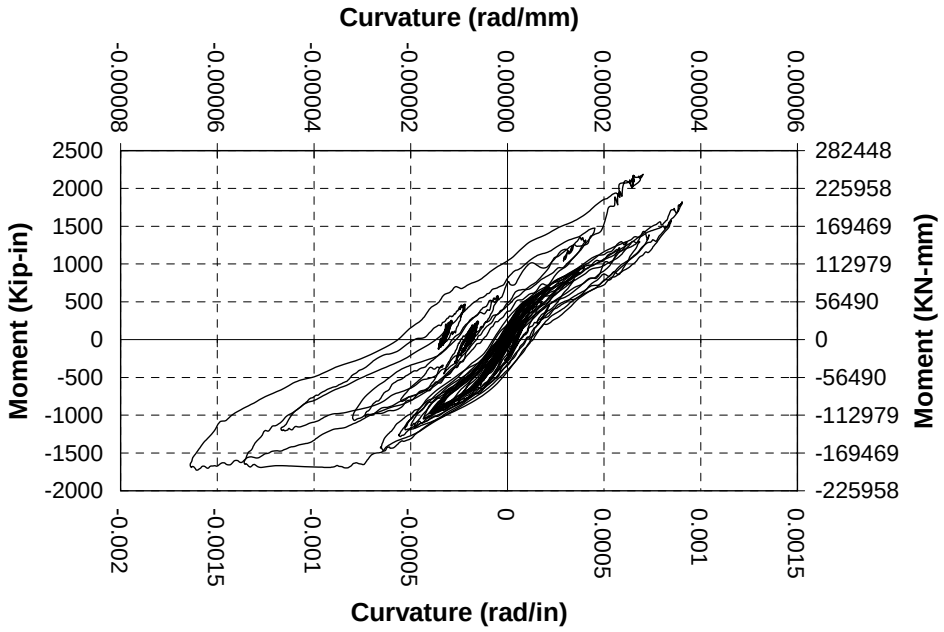


Fig. 3-162. Accumulated Moment Curvature at the First Level in SC-2R

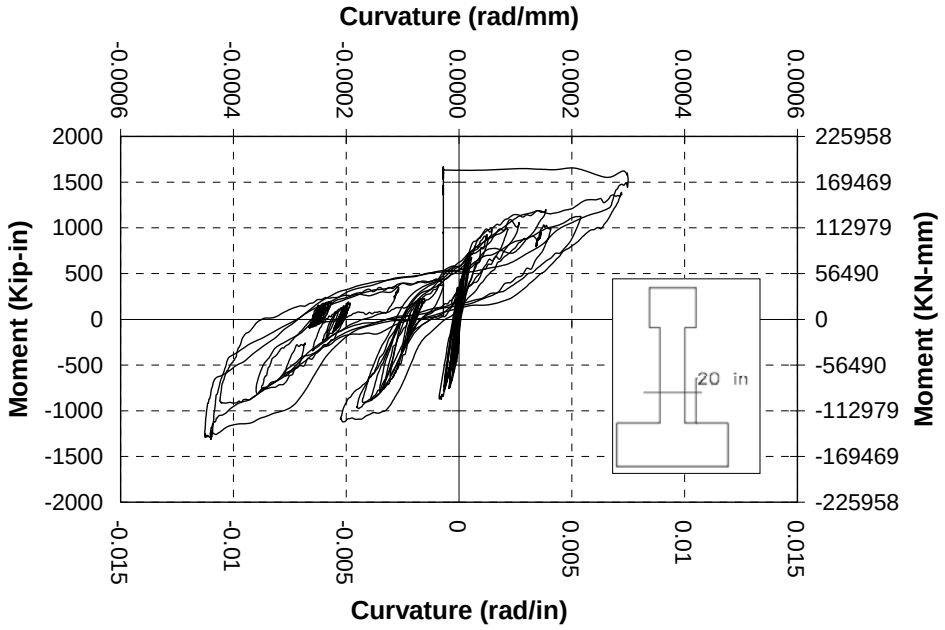


Fig. 3-163. Accumulated Moment Curvature at the Second Level in SC-2R

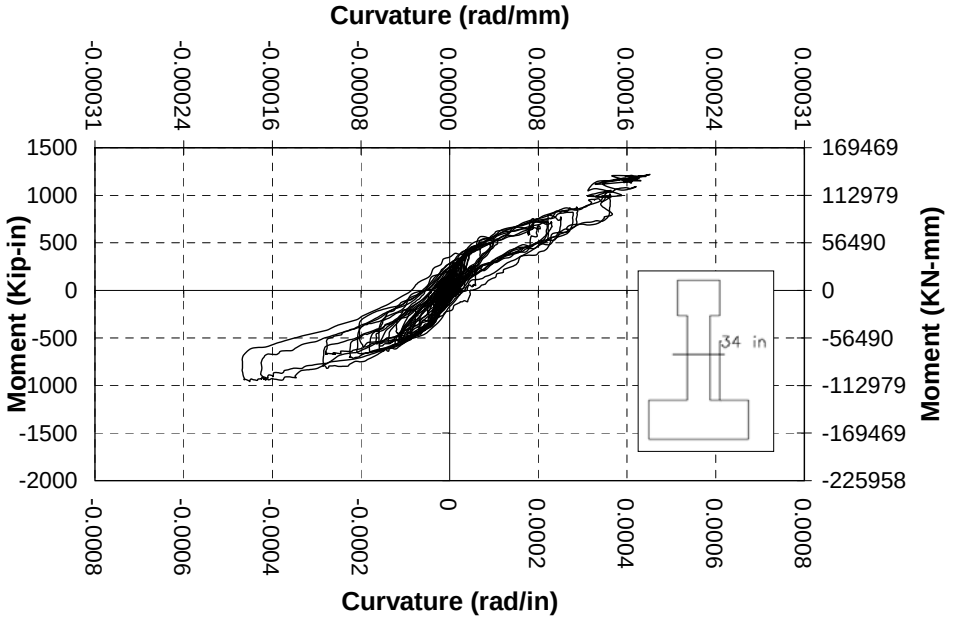


Fig. 3-164. Accumulated Moment Curvature at the Third Level in SC-2R

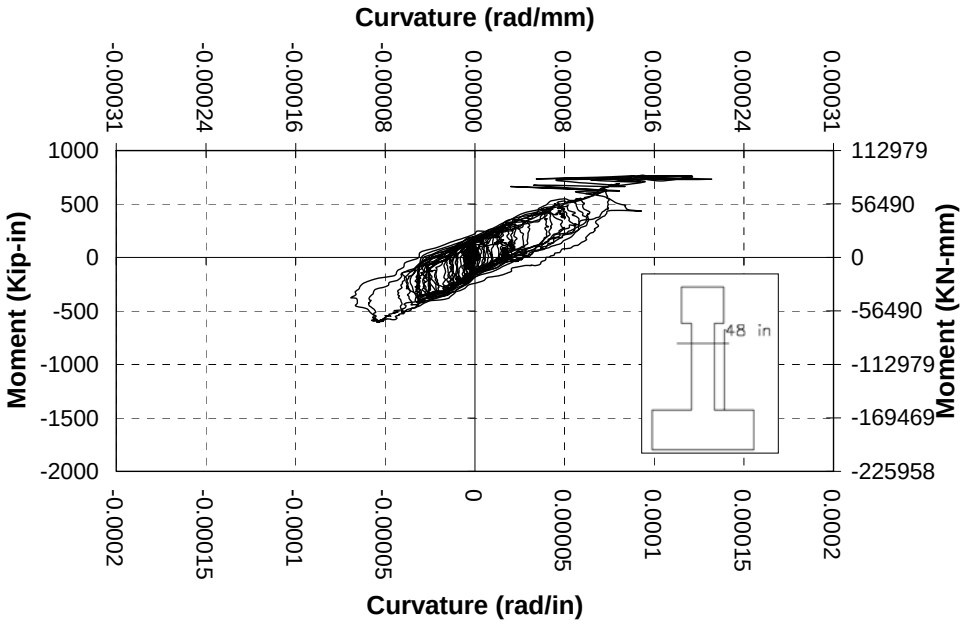


Fig. 3-165. Accumulated Moment Curvature at the Fourth Level in SC-2R

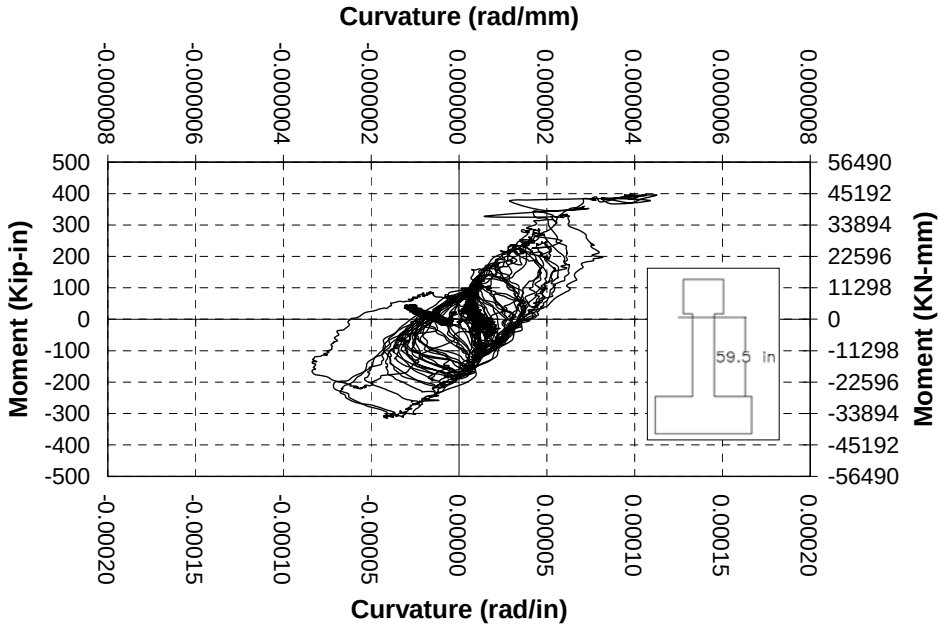


Fig. 3-166. Accumulated Moment Curvature at the Fifth Level in SC-2R

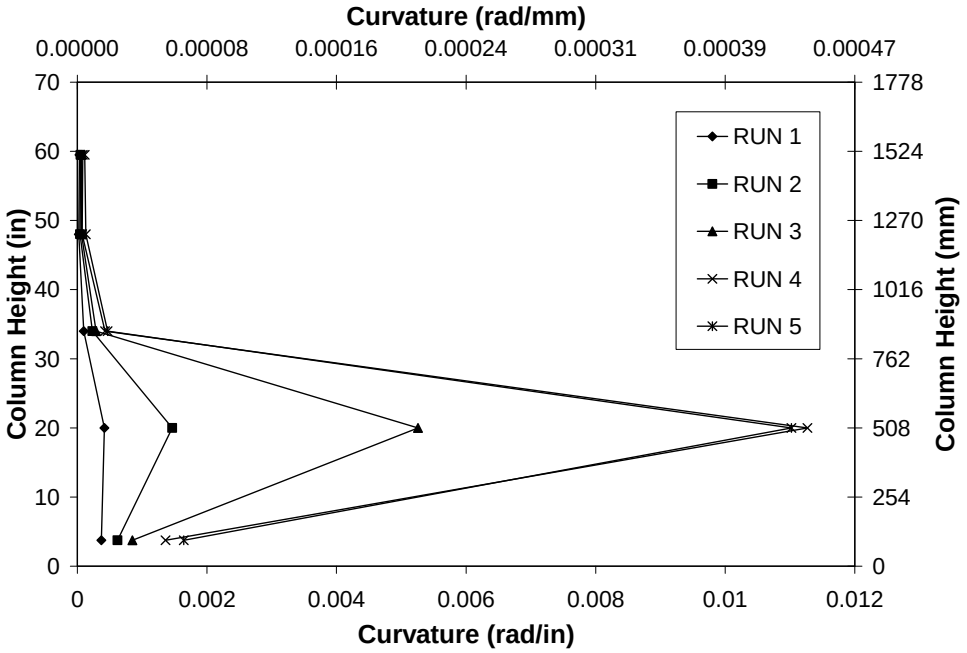


Fig. 3-167. Curvature Profile for SC-2R

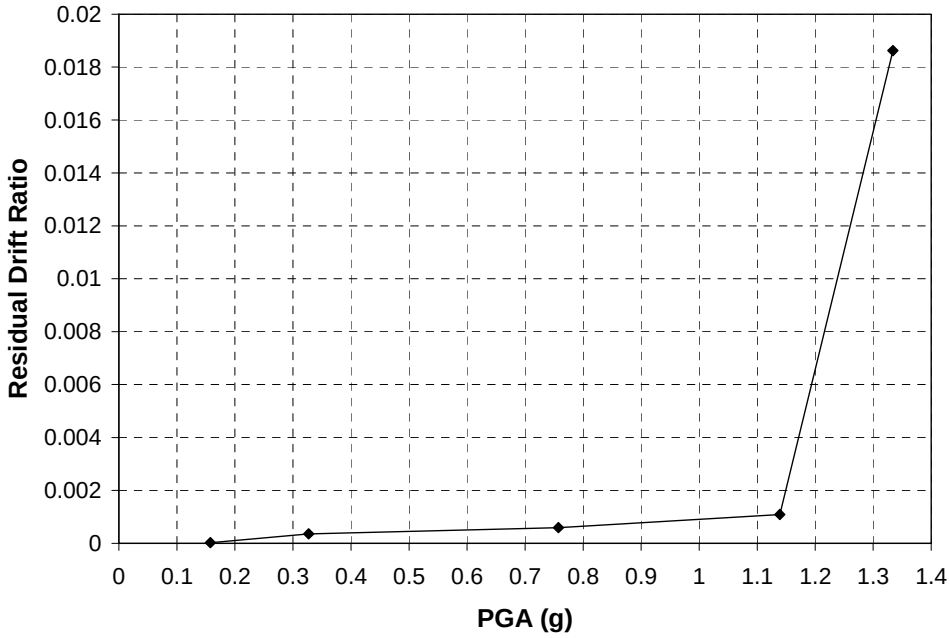


Fig. 3-168. Residual Drift Ratio vs. PGA in SC-2R

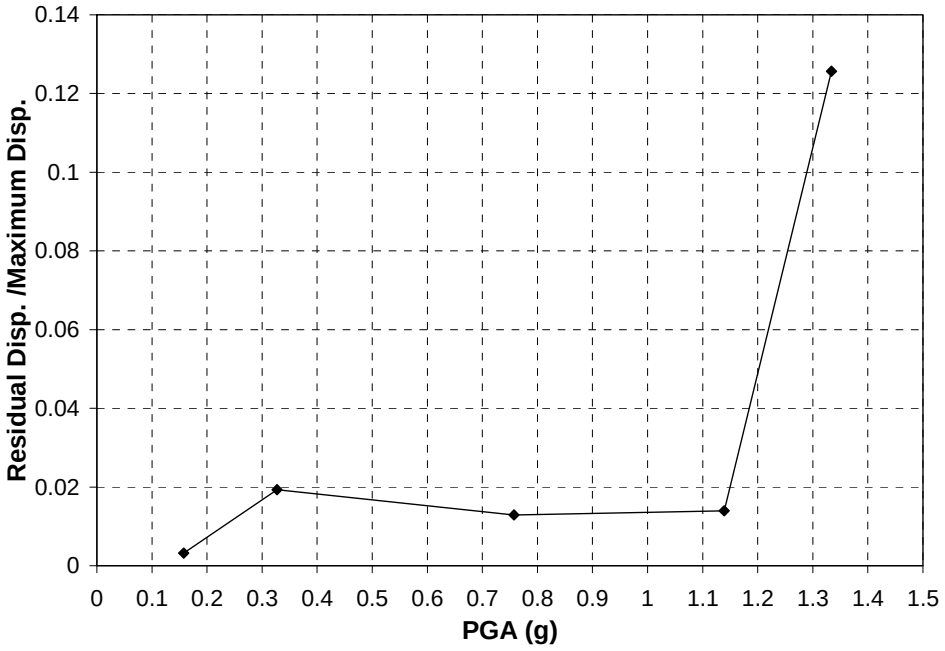


Fig. 3-169. Residual Disp. / Max. Disp. vs. PGA in SC-2R

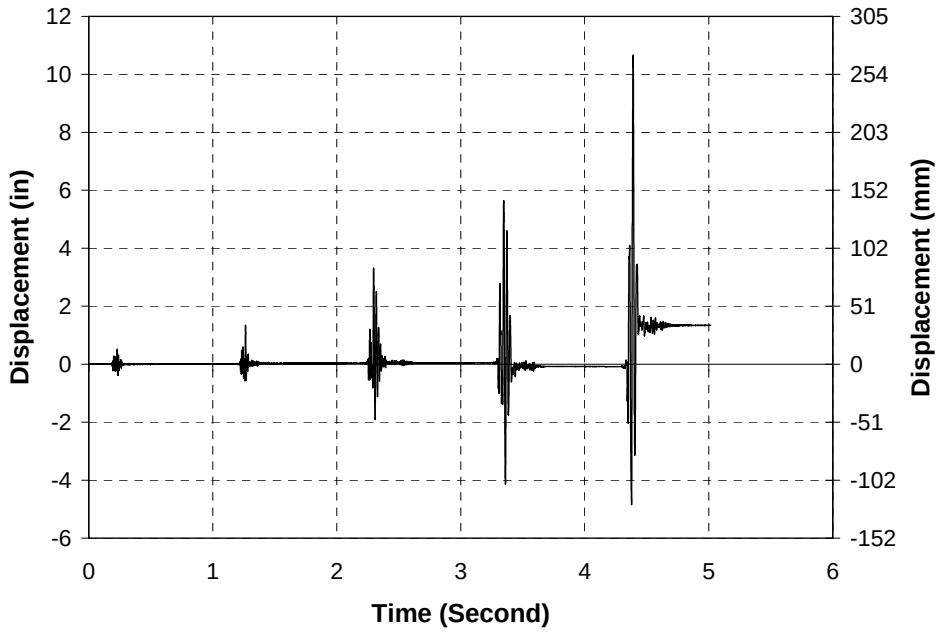


Fig. 3-170. Displacement History in Column SC-2R

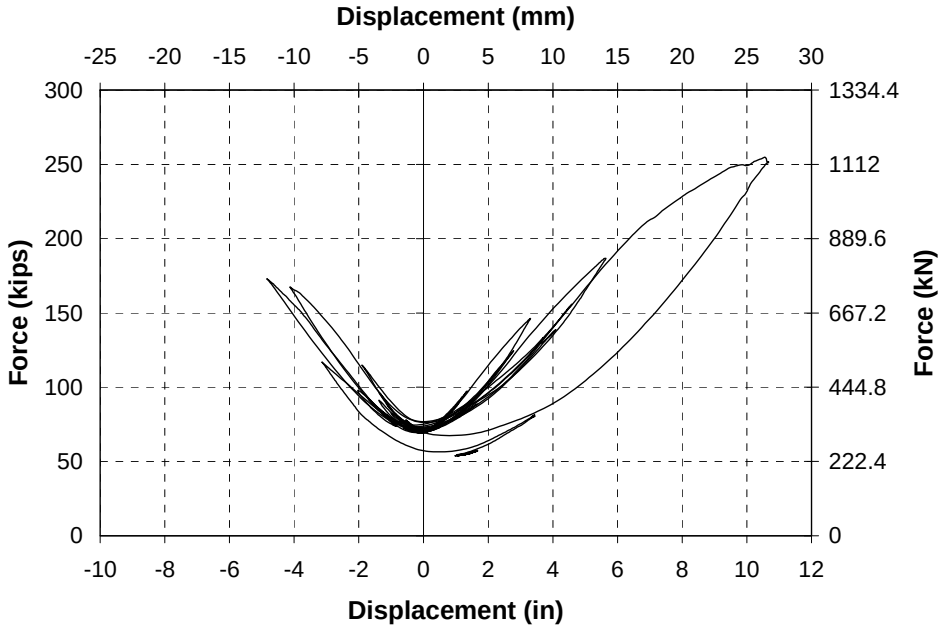


Fig. 3-171. Unbonded PT Rod Force vs. Displacement in SC-2R

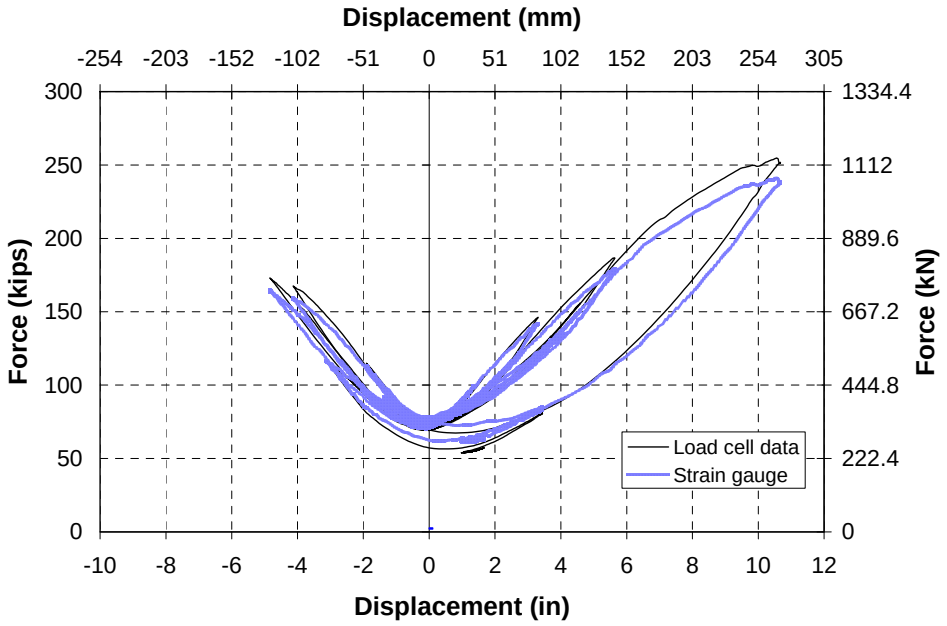


Fig. 3-172. Comparison of Unbonded PT Rod Force Measured by Load Cell and Strain Gauges in SC-2R

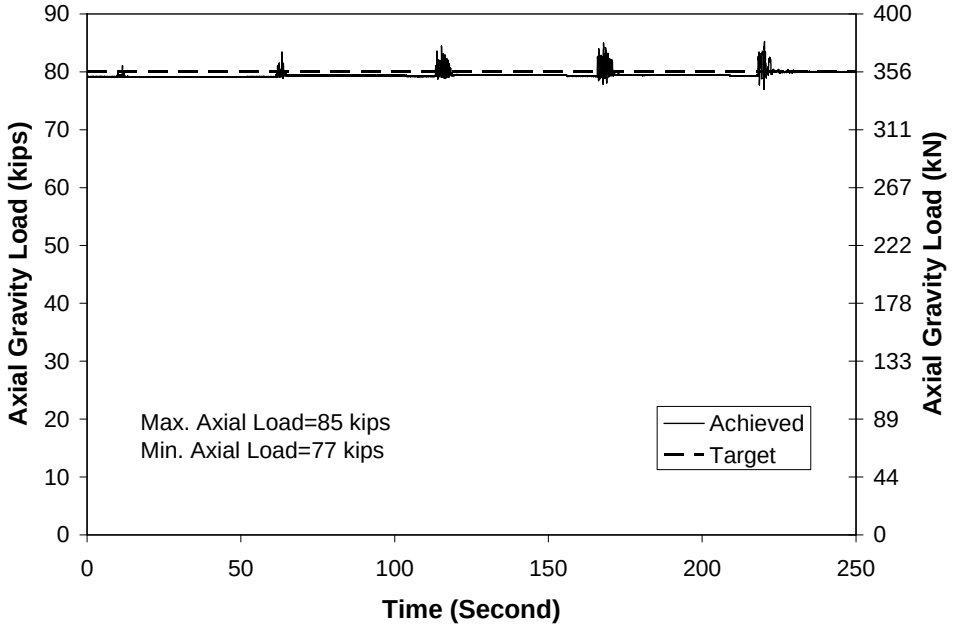


Fig. 3-173. Axial Gravity Load History on SC-2R

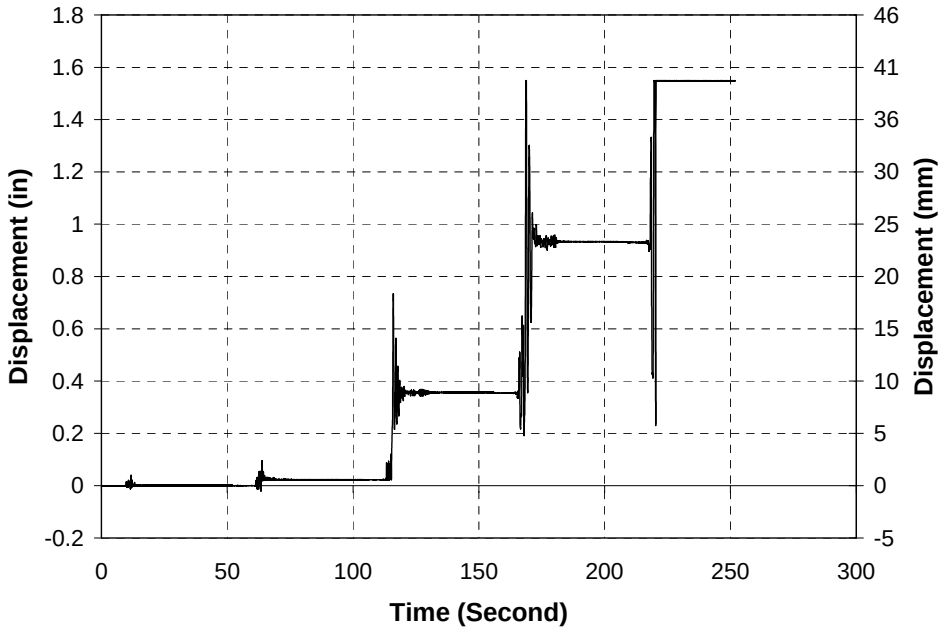


Fig. 3-174. History of Segment Separation at North Side of the SC-2R

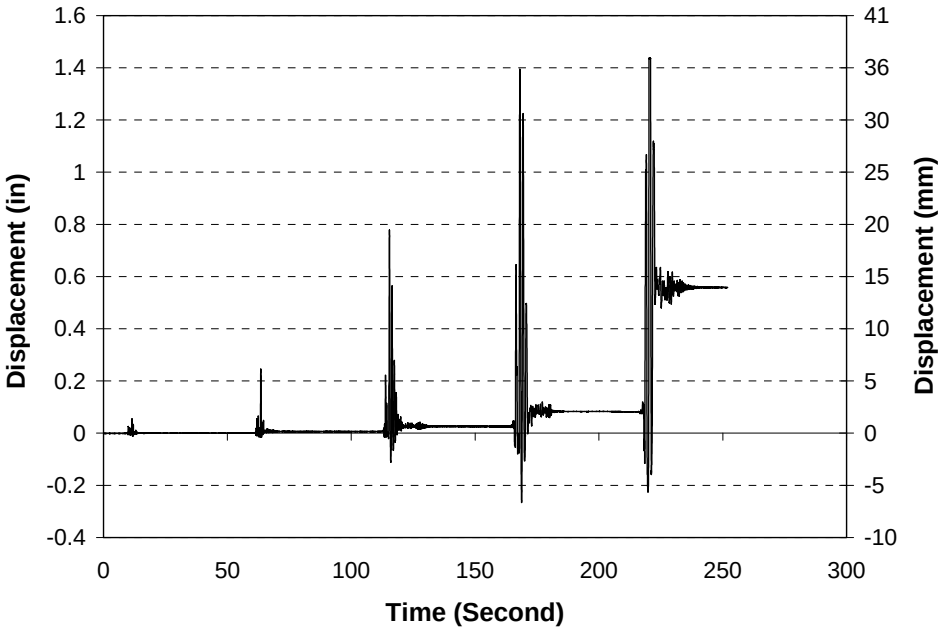
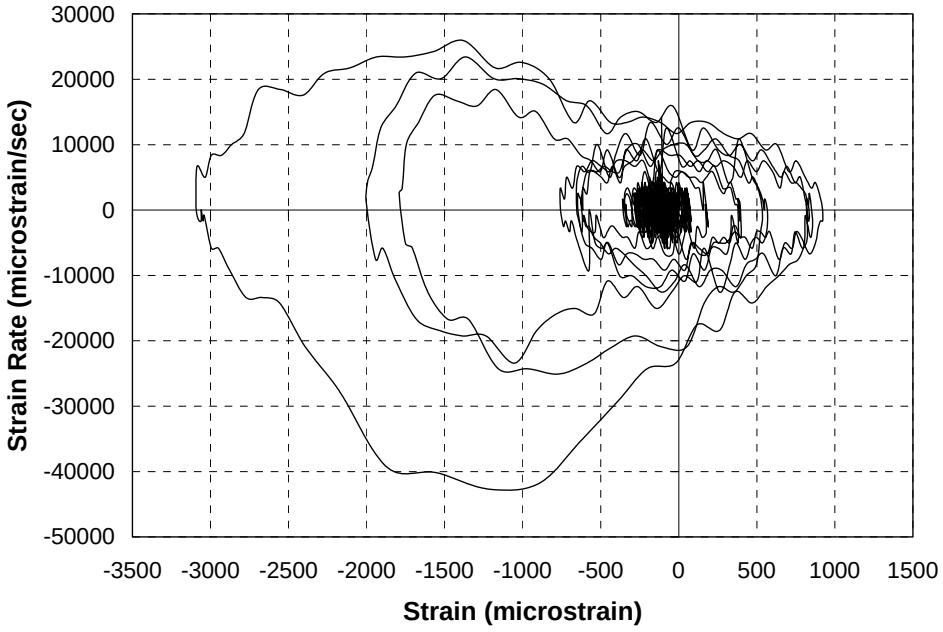
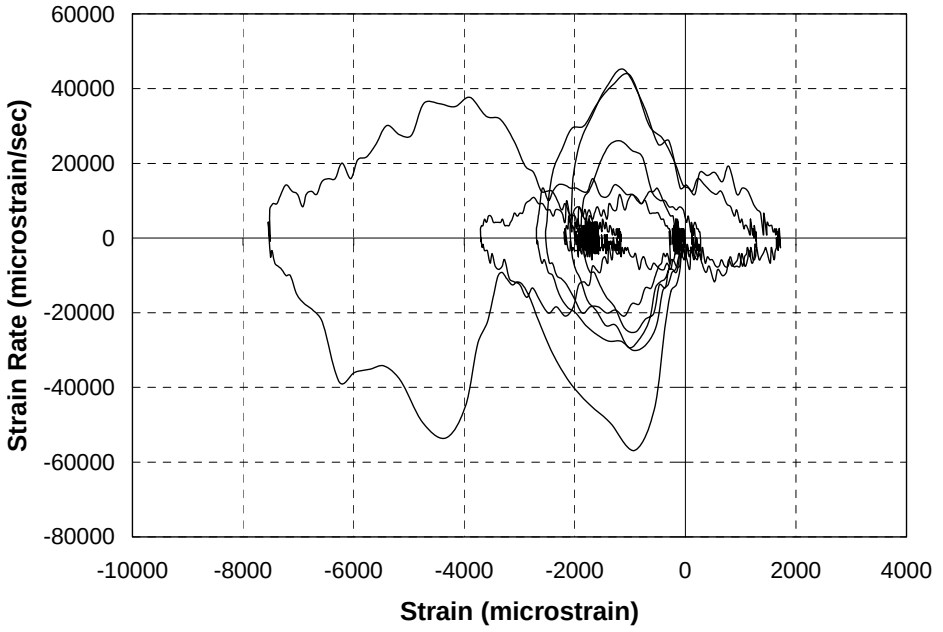


Fig. 3-175. History of Segment Separation at South Side of the SC-2R



a)



b)

Fig. 3-176. Strain Rate vs. Strain in SC-2R a) Gauge 15, Run 2 b) Gauge 12, Run 4

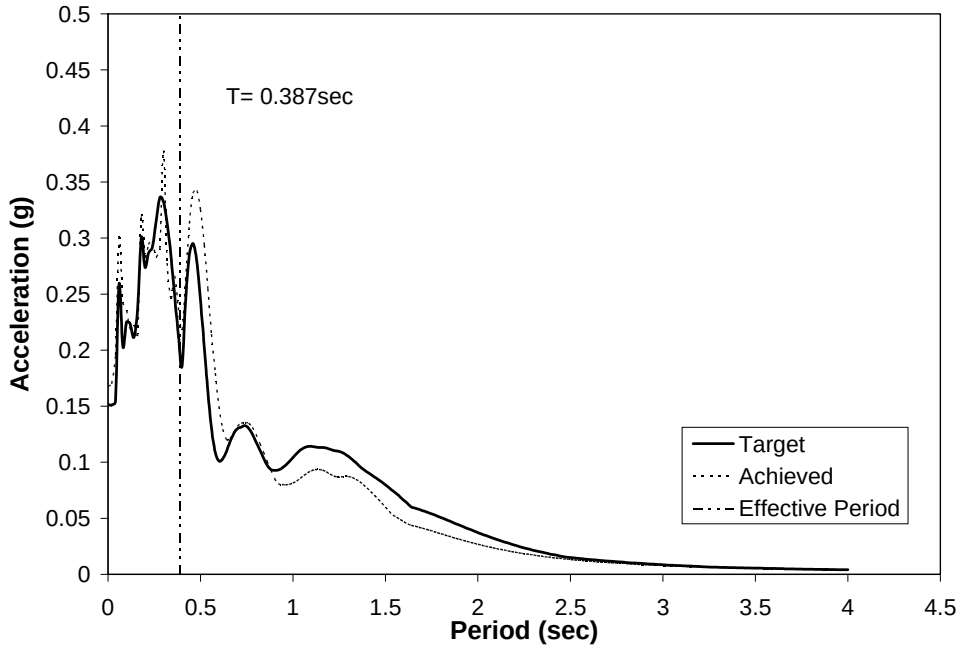


Fig. 3-177. Target vs. Achieved Ground Motion Spectra, Run-1 in SC-2R

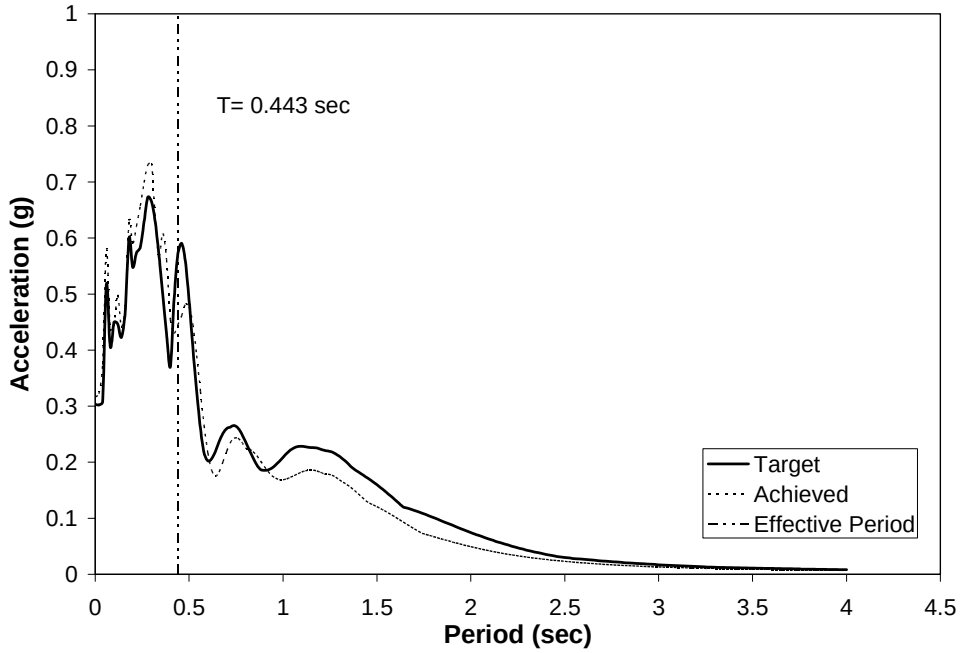


Fig. 3-178. Target vs. Achieved Ground Motion Spectra, Run-2 in SC-2R

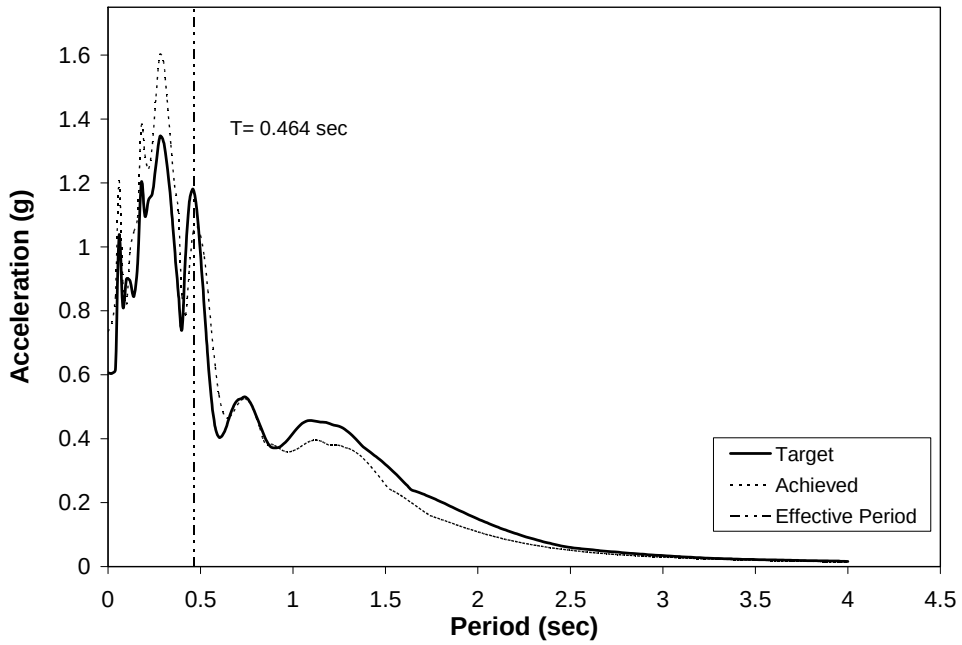


Fig. 3-179. Target vs. Achieved Ground Motion Spectra, Run-3 in SC-2R

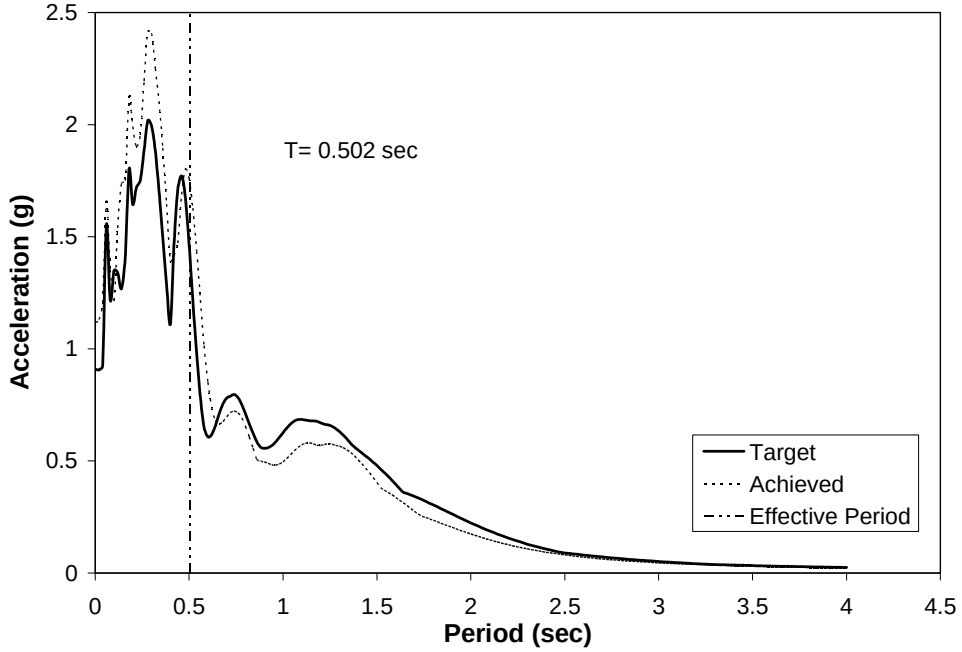


Fig. 3-180. Target vs. Achieved Ground Motion Spectra, Run-4 in SC-2R

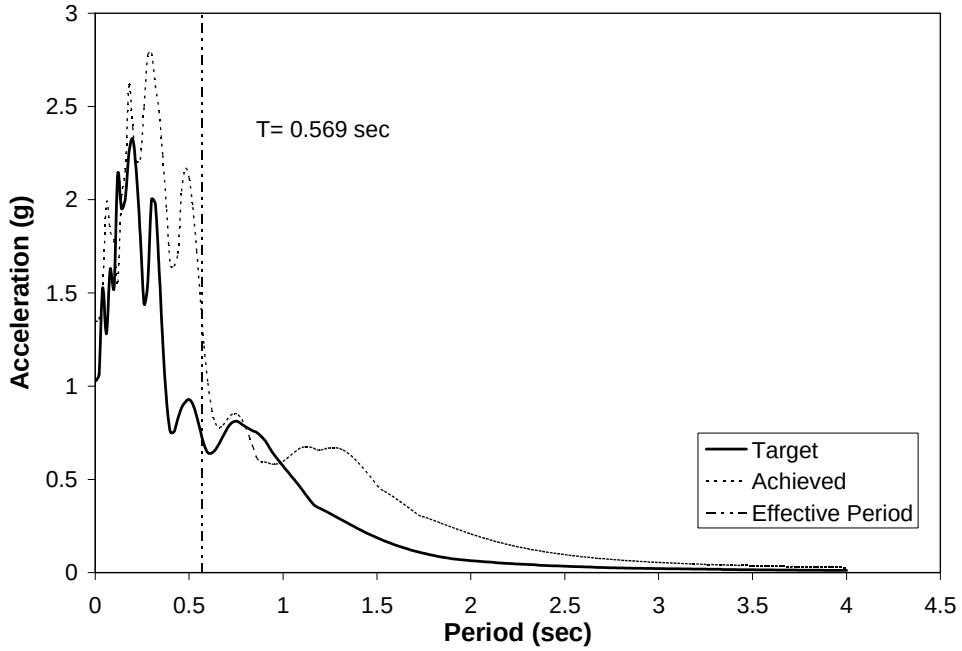
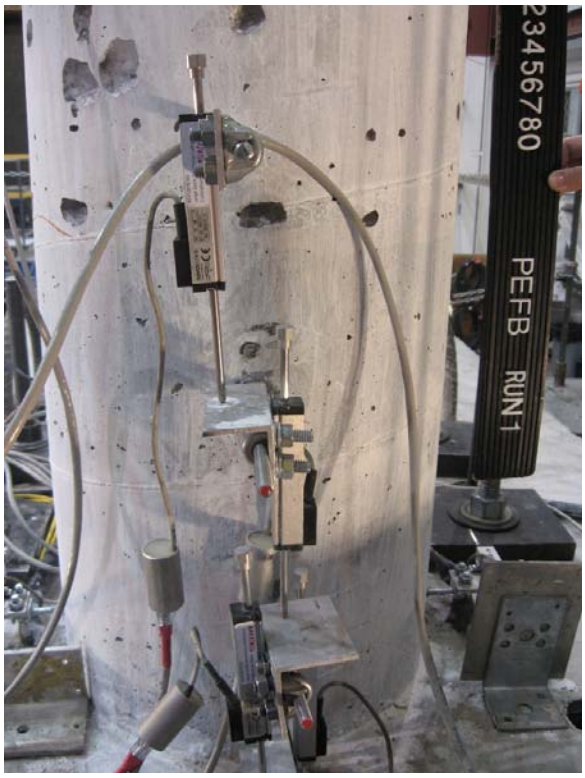
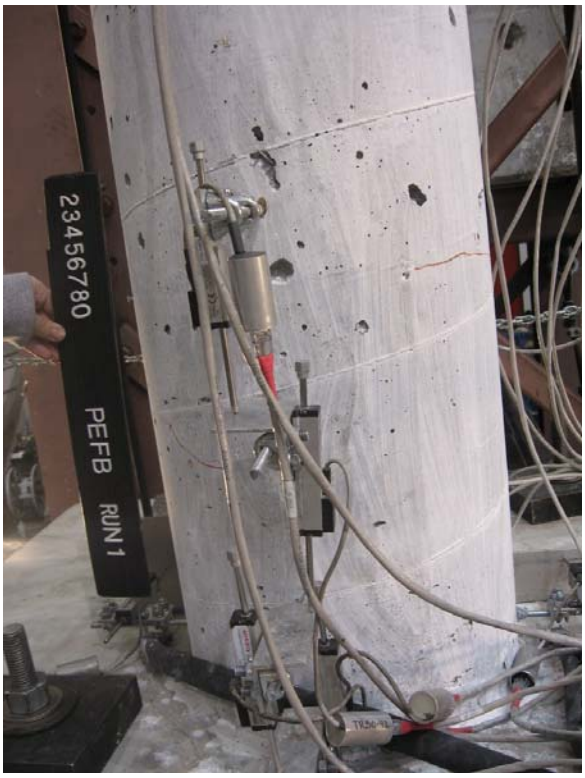


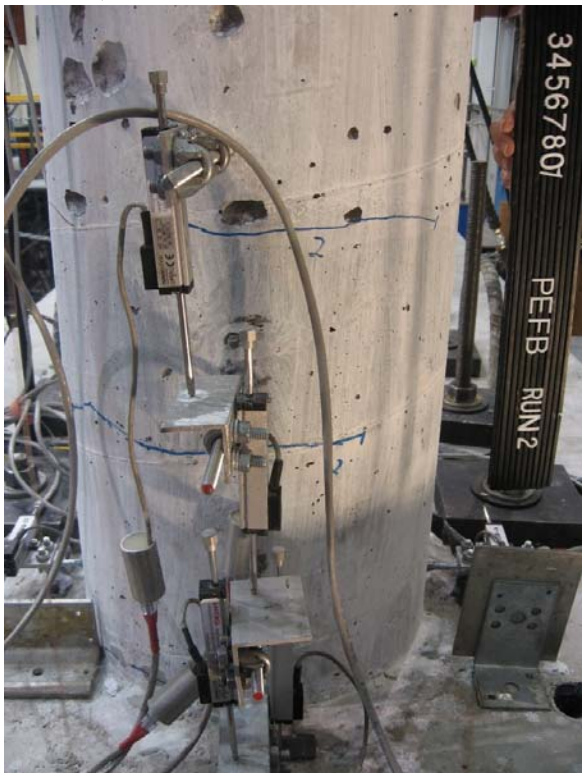
Fig. 3-181. Target vs. Achieved Ground Motion Spectra, Run-5 in SC-2R



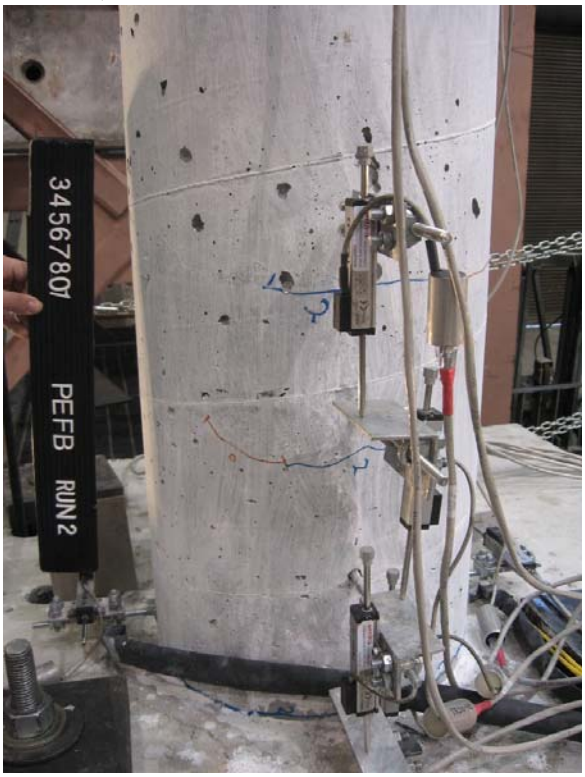
a) RC-ECC Column, North, Run-1



b) RC-ECC Column, North, Run-1

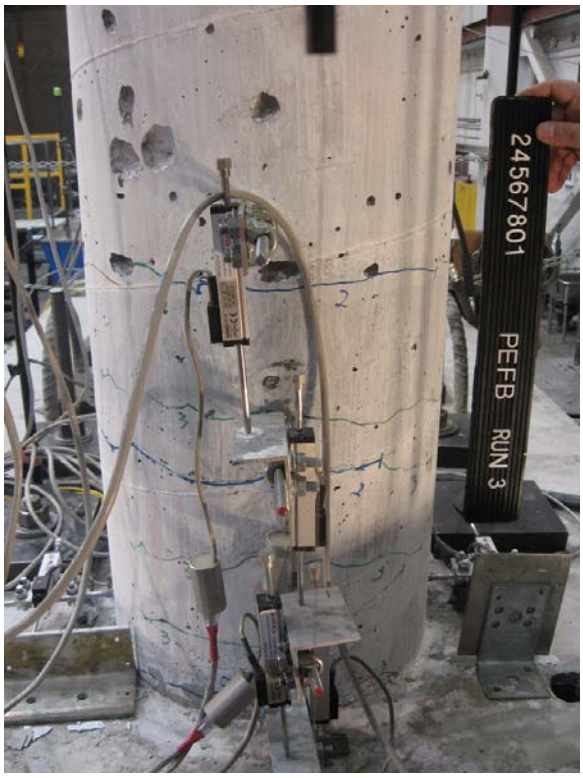


c) RC-ECC Column, North, Run-2

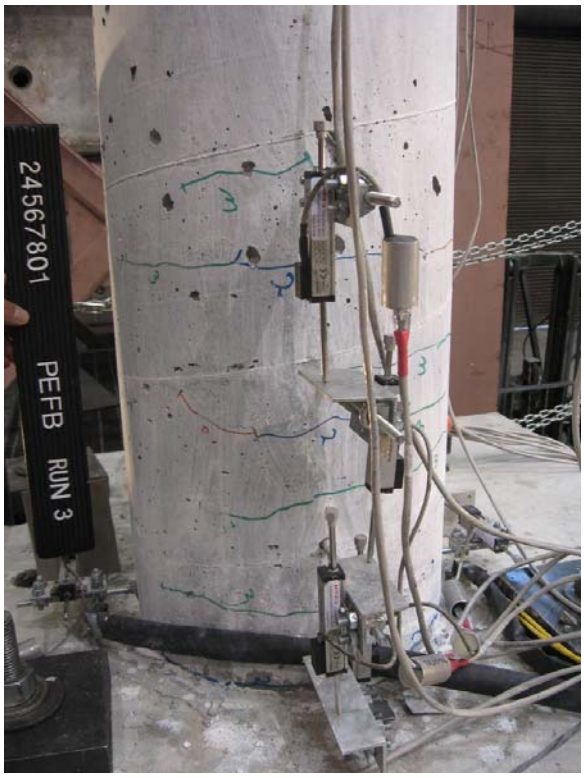


d) RC-ECC Column, South, Run-2

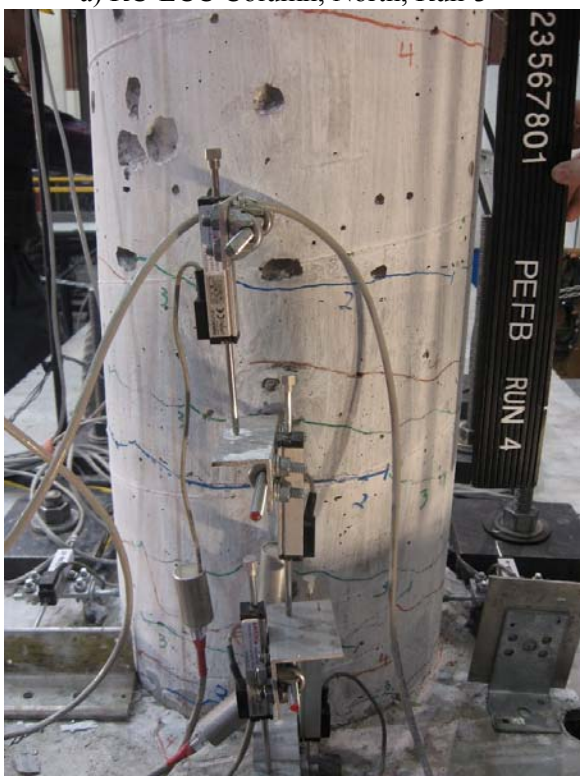
Fig. 3-182. Damage Progression Photographs for RC-ECC Column, Bottom, Run 1 and 2



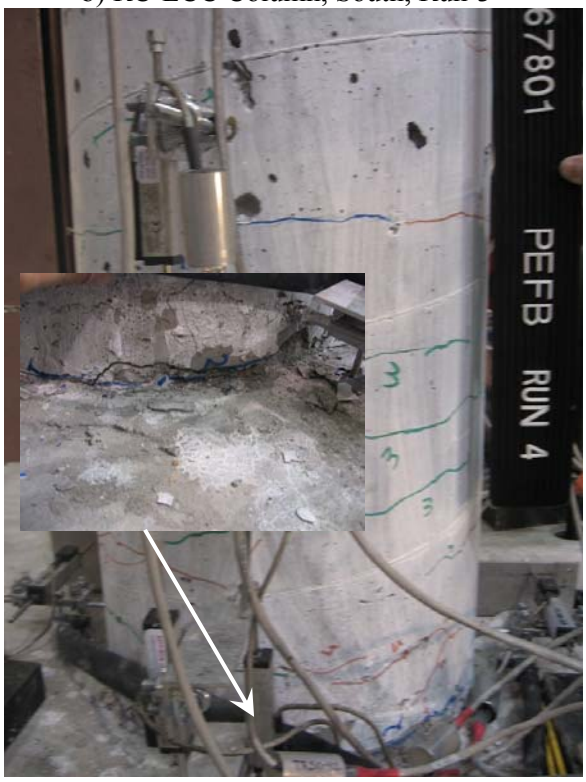
a) RC-ECC Column, North, Run-3



b) RC-ECC Column, South, Run-3

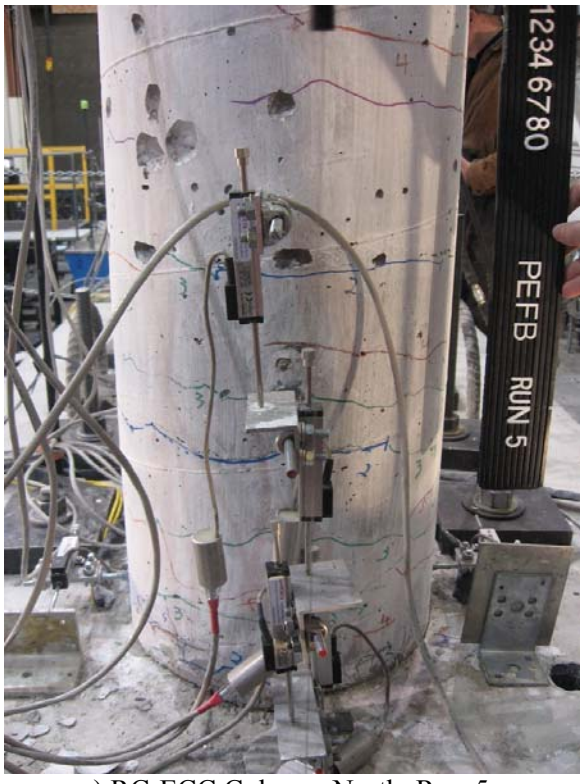


c) RC-ECC Column, North, Run-4

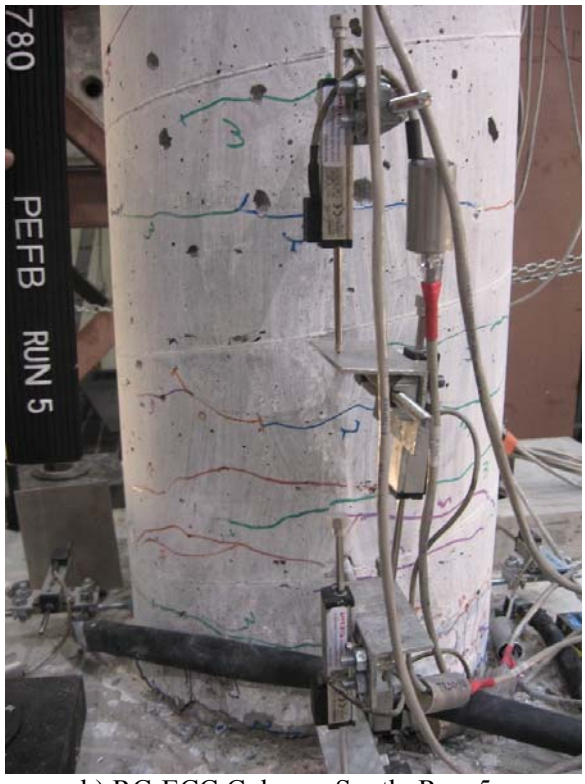


d) RC-ECC Column, South, Run-4

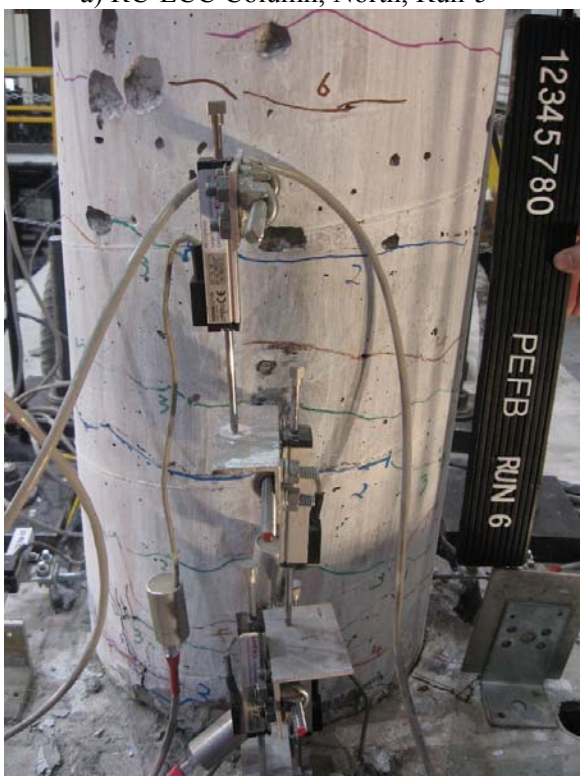
Fig. 3-183. Damage Progression Photographs for RC-ECC Column, Bottom, Run 3 and 4



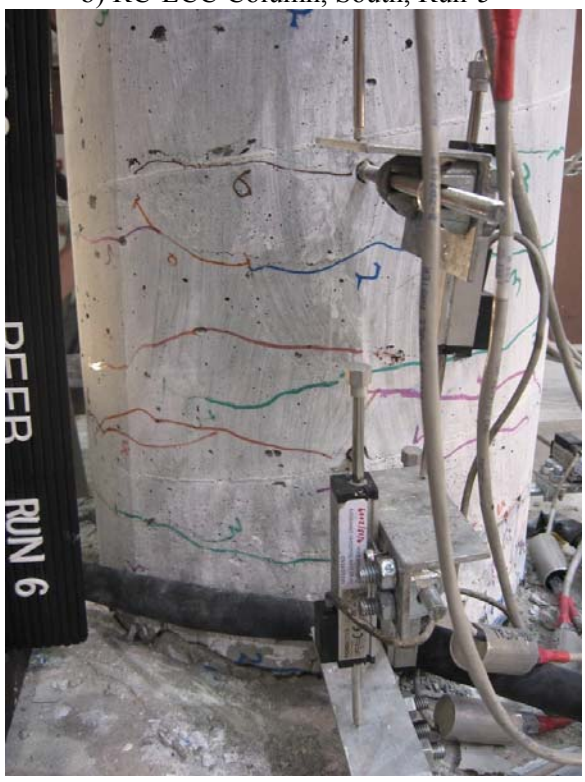
a) RC-ECC Column, North, Run-5



b) RC-ECC Column, South, Run-5



c) RC-ECC Column, North, Run-6



d) RC-ECC Column, South, Run-6

Fig. 3-184. Damage Progression Photographs for RC-ECC Column, Bottom, Run 5 and 6

a) RC-ECC Column, North, Run-6

b) RC-ECC Column, South, Run-6

Fig. 3-185. Rupture of Long. Bars in RC-ECC Column at Run 6

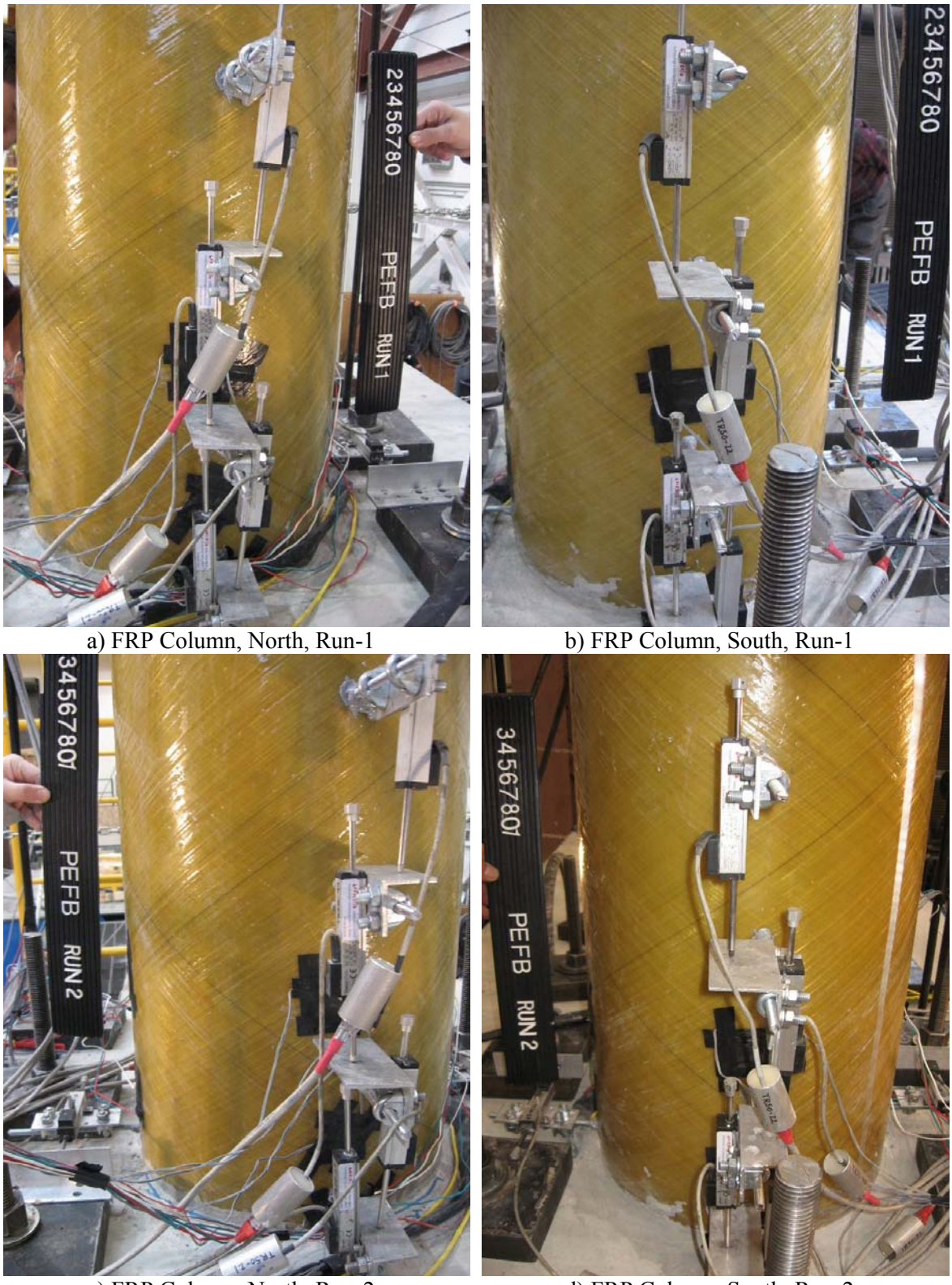
a) RC-ECC Column, North, Run-6

b) RC-ECC Column, South, Run-6

c) RC-ECC Column, East, Run-6

d) RC-ECC Column, West, Run-6

Fig. 3-186. RC-ECC Column Condition, Top, Run 6



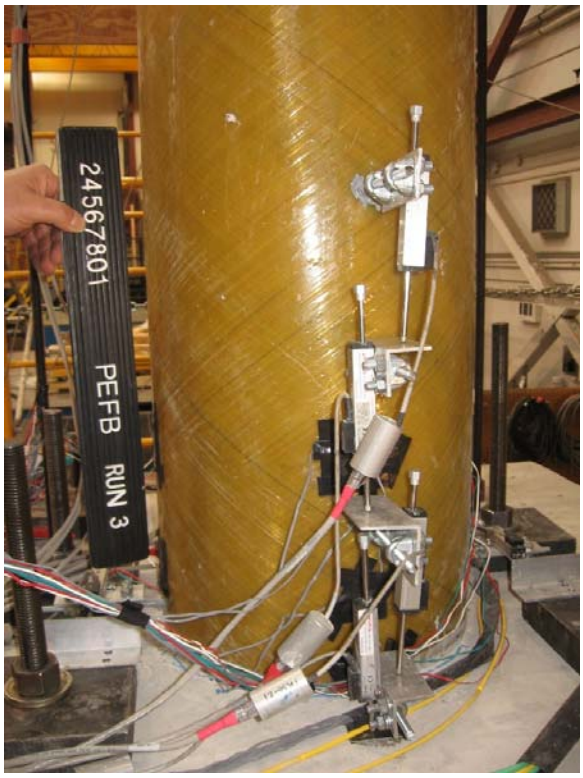
a) FRP Column, North, Run-1

b) FRP Column, South, Run-1

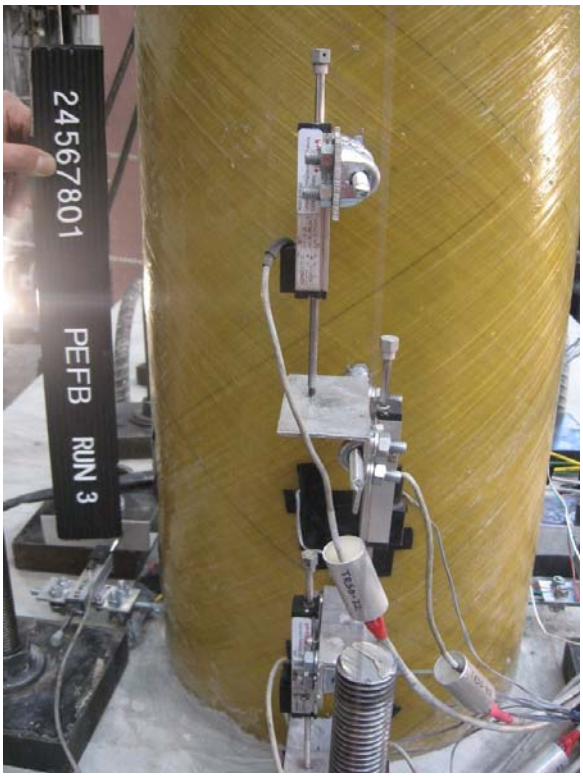
c) FRP Column, North, Run-2

d) FRP Column, South, Run-2

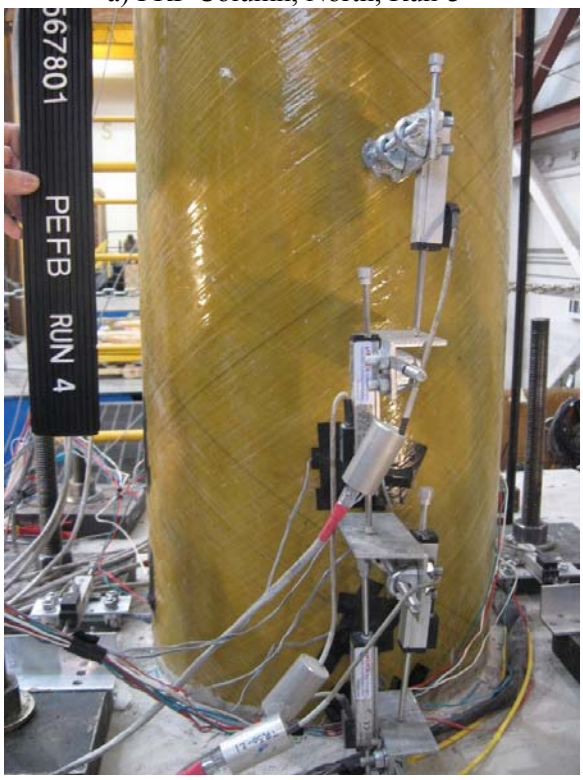
Fig. 3-187. Damage Progression Photographs for FRP Column, Bottom, Run 1 and 2



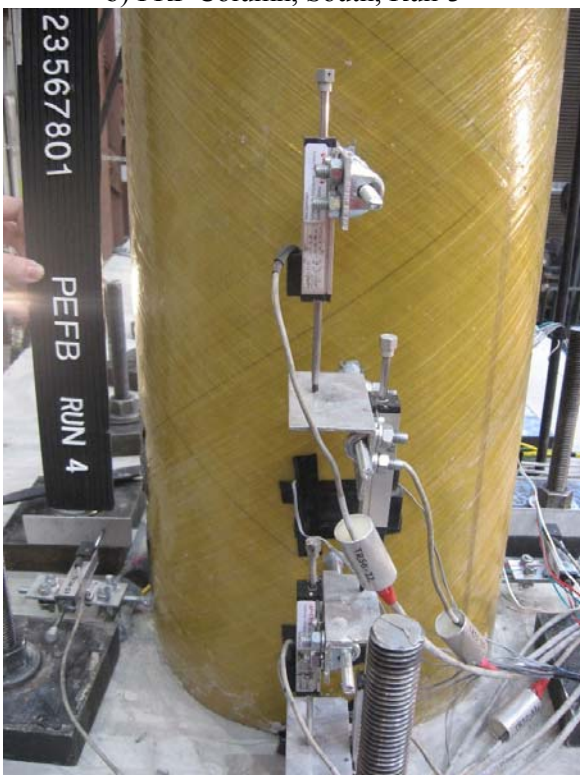
a) FRP Column, North, Run-3



b) FRP Column, South, Run-3



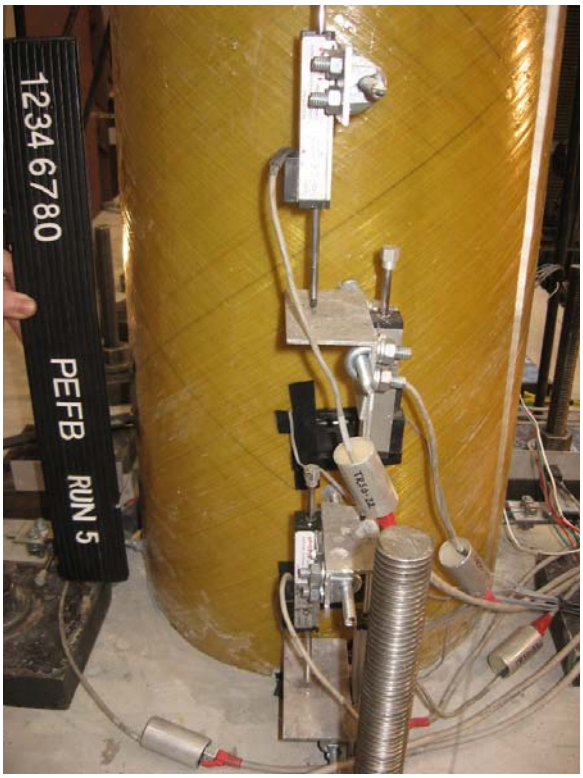
c) FRP Column, North, Run-4



d) FRP Column, South, Run-4

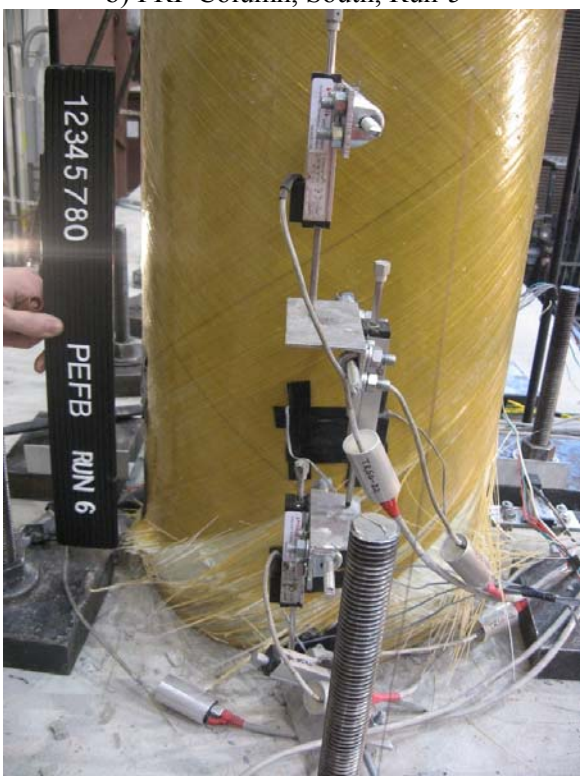
Fig. 3-188. Damage Progression Photographs for FRP Column, Bottom, Run 3 and 4

a) FRP Column, North, Run-5



b) FRP Column, South, Run-5

c) FRP Column, North, Run-6



d) FRP Column, South, Run-6

Fig. 3-189. Damage Progression Photographs for FRP Column, Bottom, Run 5 and 6

a) FRP Rupture, South, Run 6

b) FRP Buckling, North, Run 6

c) Horizontal Crack, South, Run 6

d) Two Buuckled bars, South, Run 6

Fig. 3-190. FRP Column Failure after Run 6

a) FRP Column, North, Run-6

b) FRP Column, South, Run-6

c) FRP Column, East, Run-6

d) FRP Column, West, Run-6

Fig. 3-191. RC-ECC Column Condition, Top, Run 6

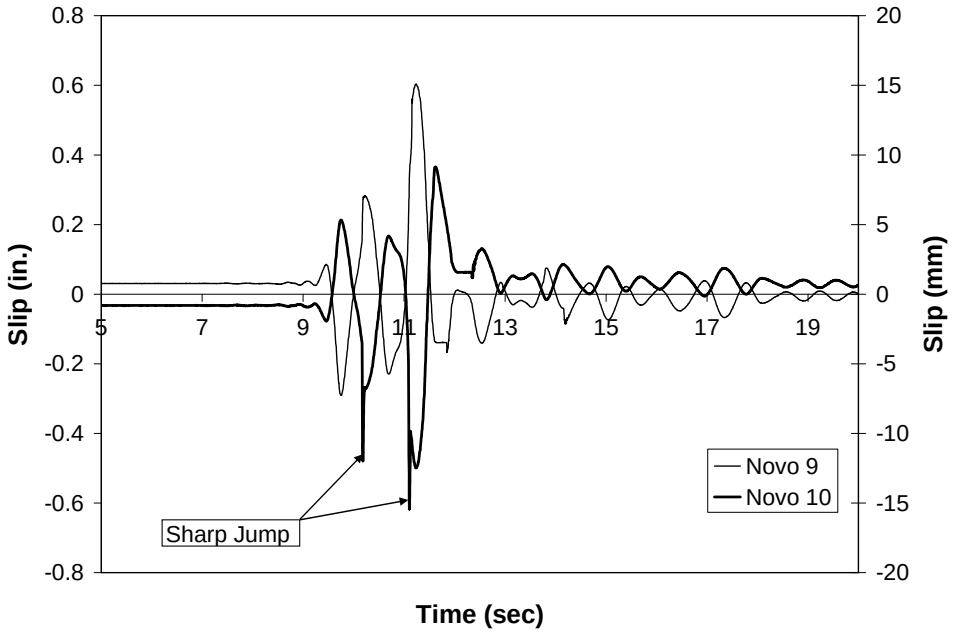


Fig. 3-192. Measured Sliding at Run 6 before Data Correction

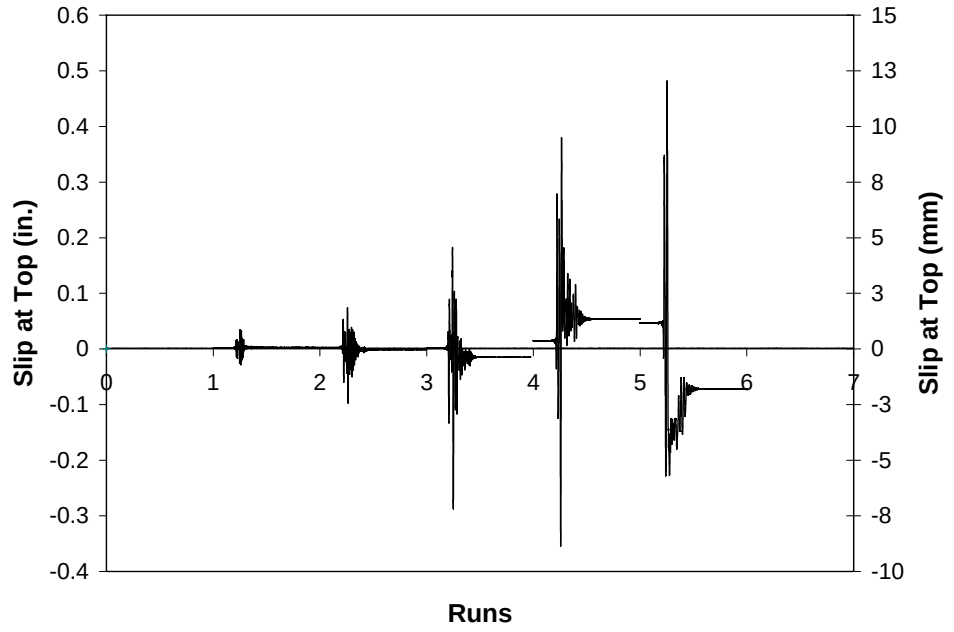


Fig. 3-193. Hinge Slip in RC-ECC Column

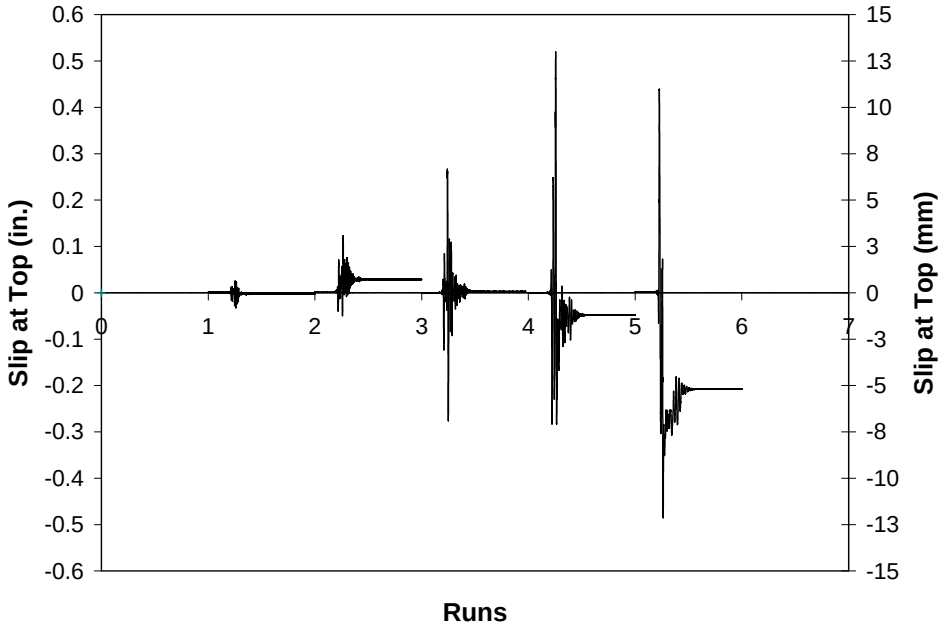


Fig. 3-194. Hinge Slip in FRP Column

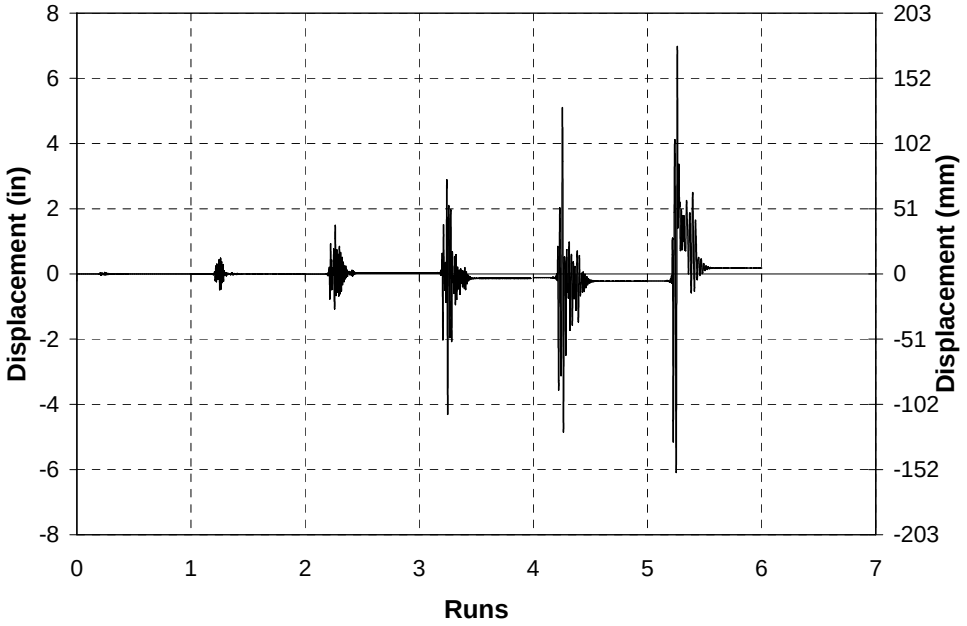


Fig. 3-195. RC-ECC Column Pure Deformation History

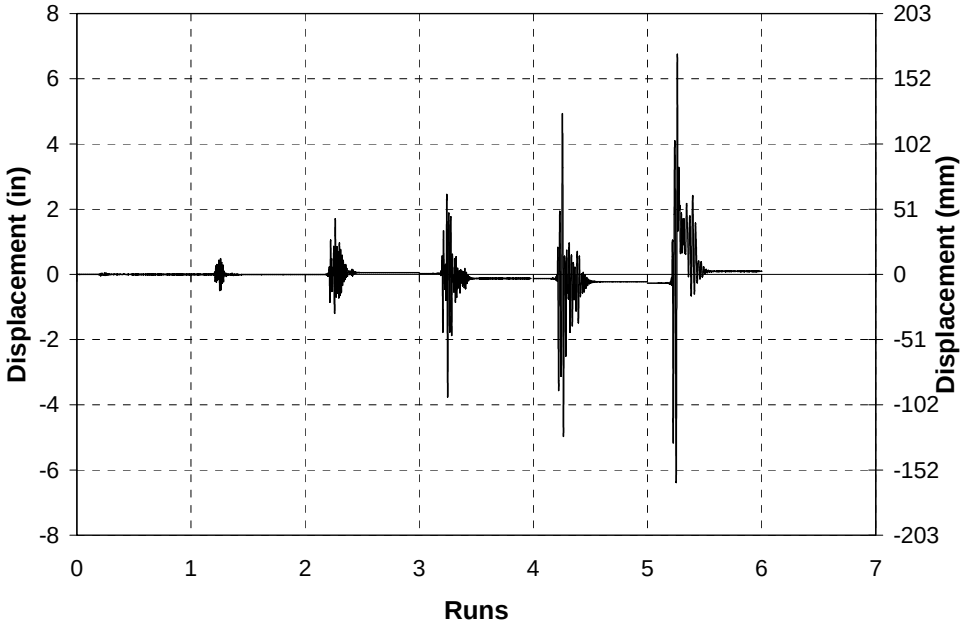


Fig. 3-196. FRP Column Pure Deformation History

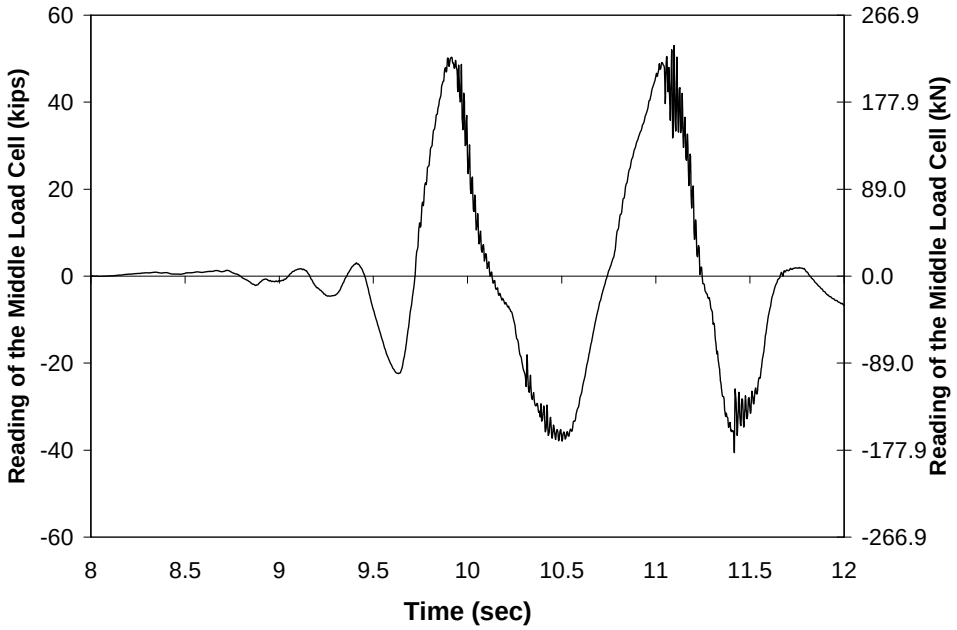


Fig. 3-197. Measured Axial Load in the Middle Load Cell, Run 6

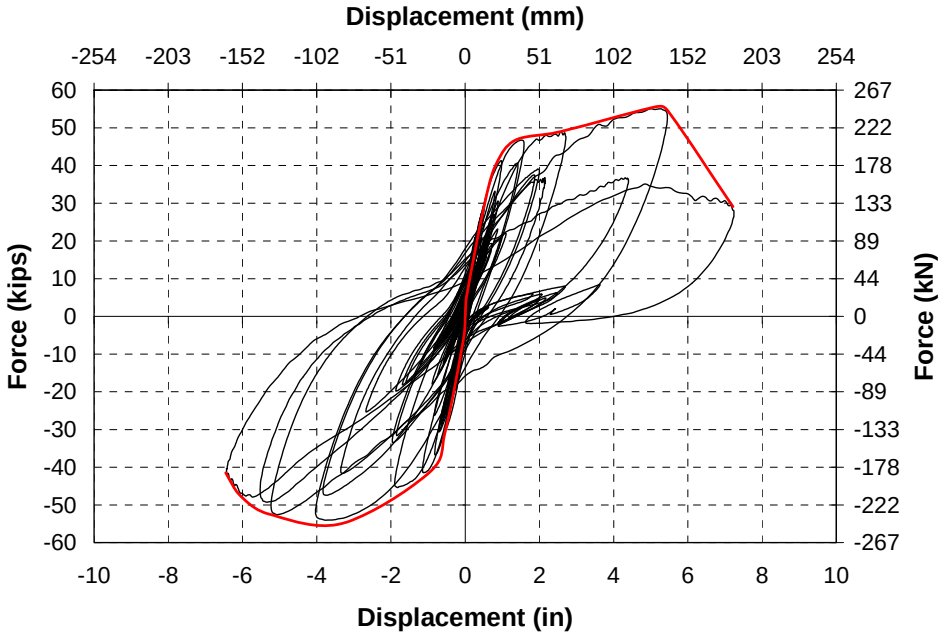


Fig. 3-198. Accumulated Force-Displacement Hysteresis Curve for PEFB Bent

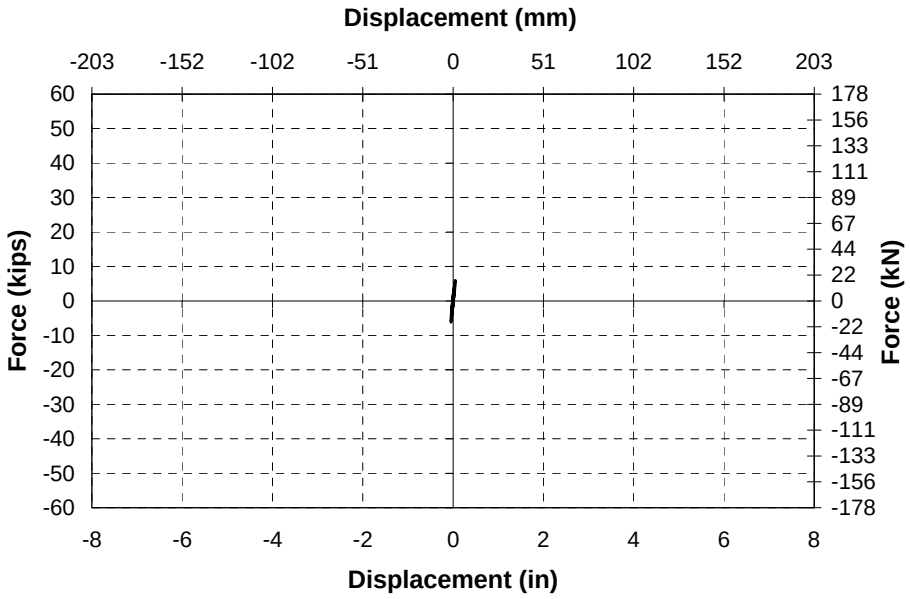


Fig. 3-199. Force-Displacement Hysteresis Curve for Run 1 in PEFB Bent

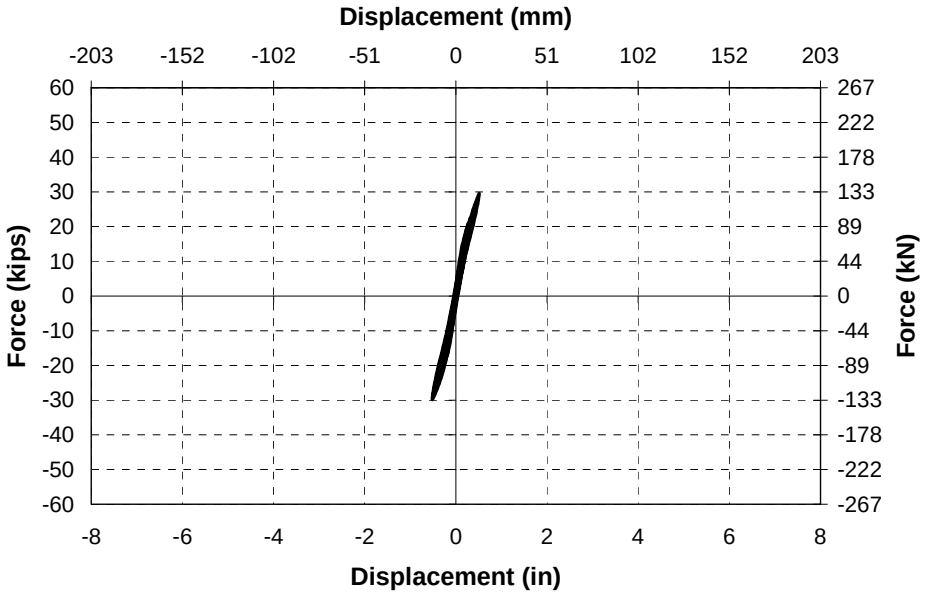


Fig. 3-200. Force-Displacement Hysteresis Curve for Run 2 in PEFB Bent

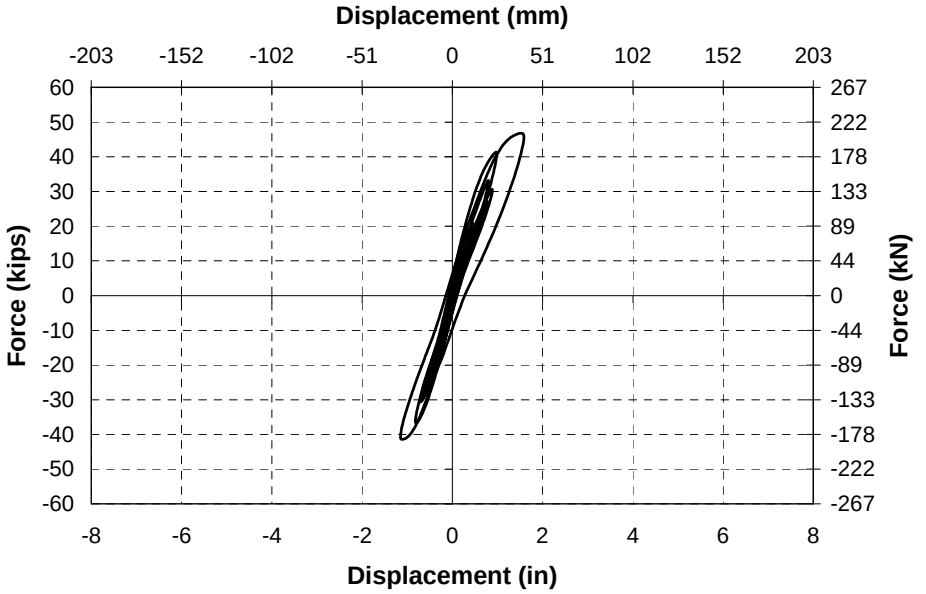


Fig. 3-201. Force-Displacement Hysteresis Curve for Run 3 in PEFB Bent

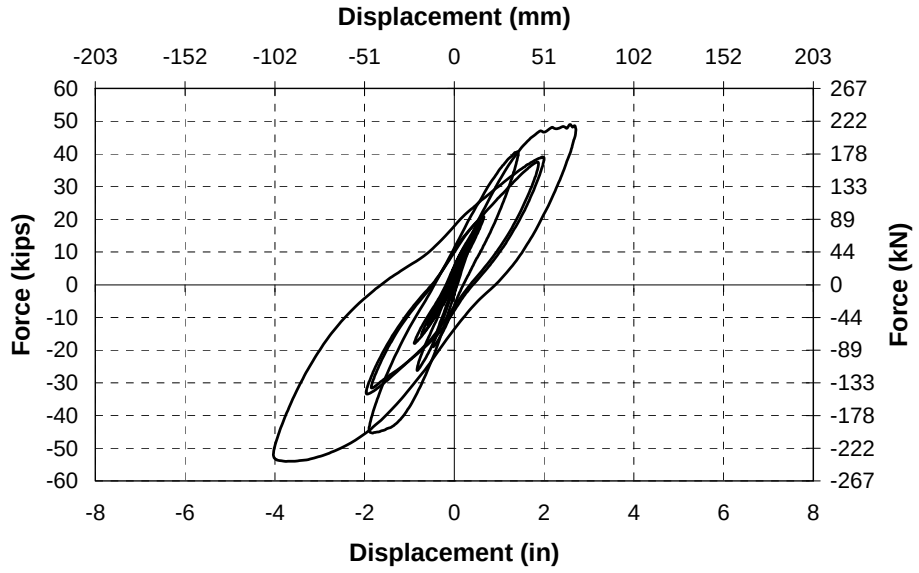


Fig. 3-202. Force-Displacement Hysteresis Curve for Run 4 in PEFB Bent

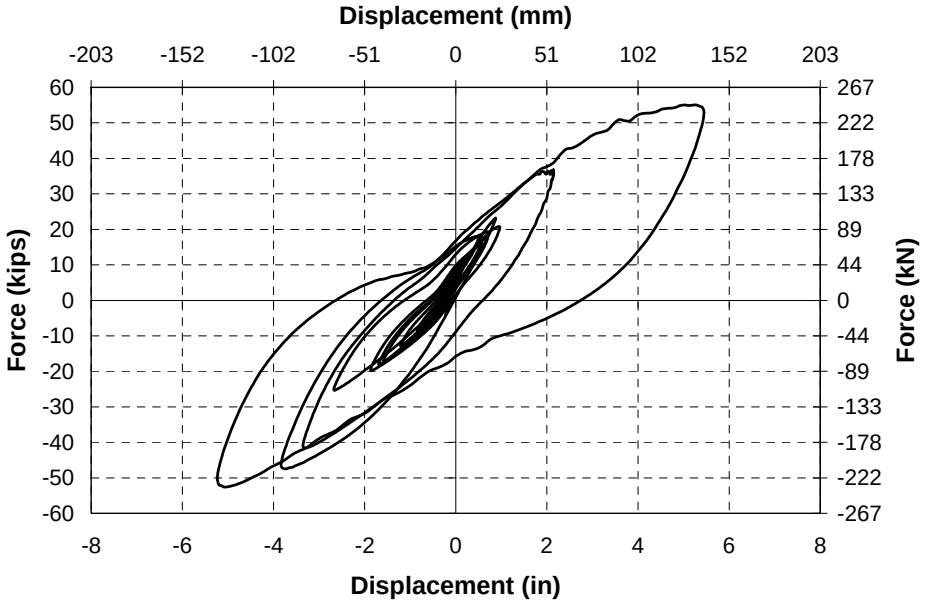


Fig. 3-203. Force-Displacement Hysteresis Curve for Run 5 in PEFB Bent

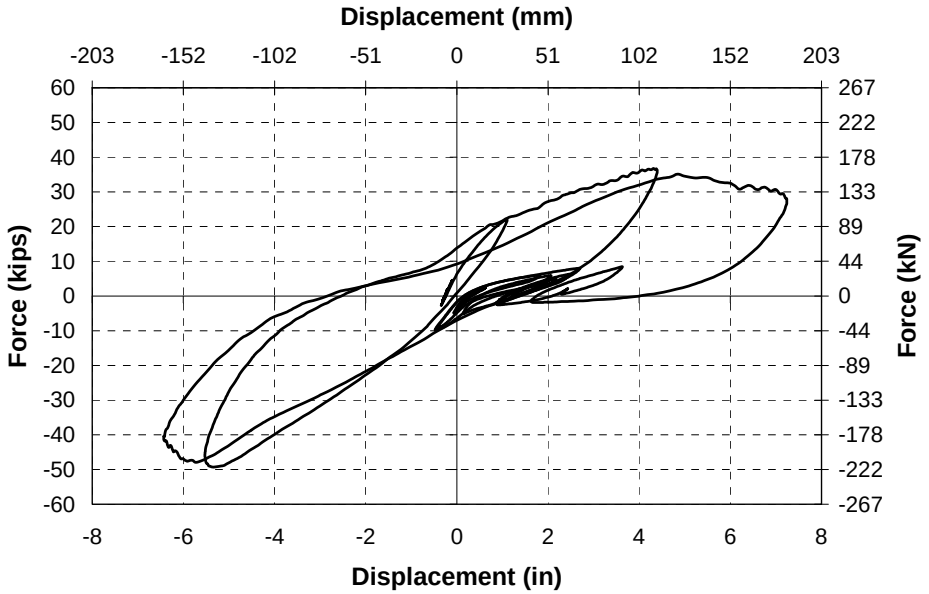


Fig. 3-204. Force-Displacement Hysteresis Curve for Run 6 in PEFB Bent

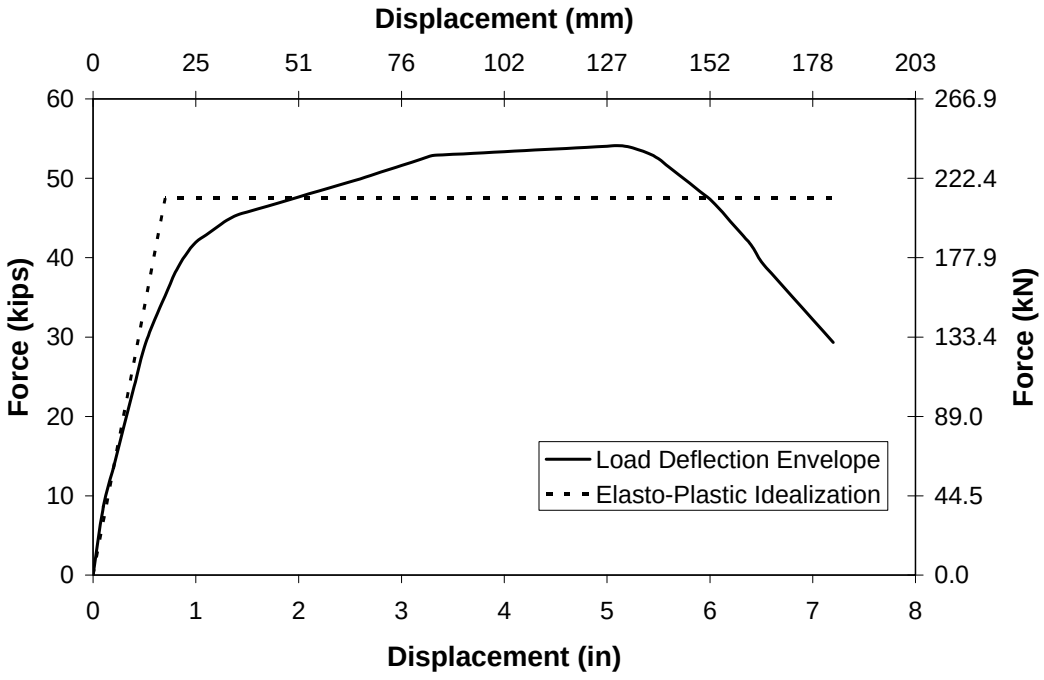


Fig. 3-205. Backbone Curve of PEFB Bent

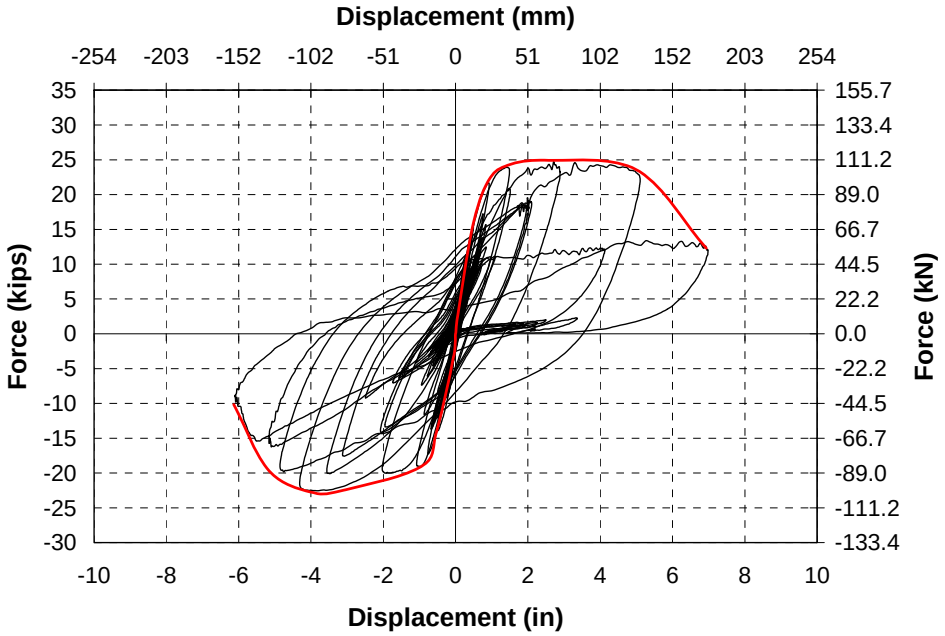


Fig. 3-206. Accumulated Force-Displacement Hysteresis Curve for RC- ECC Column

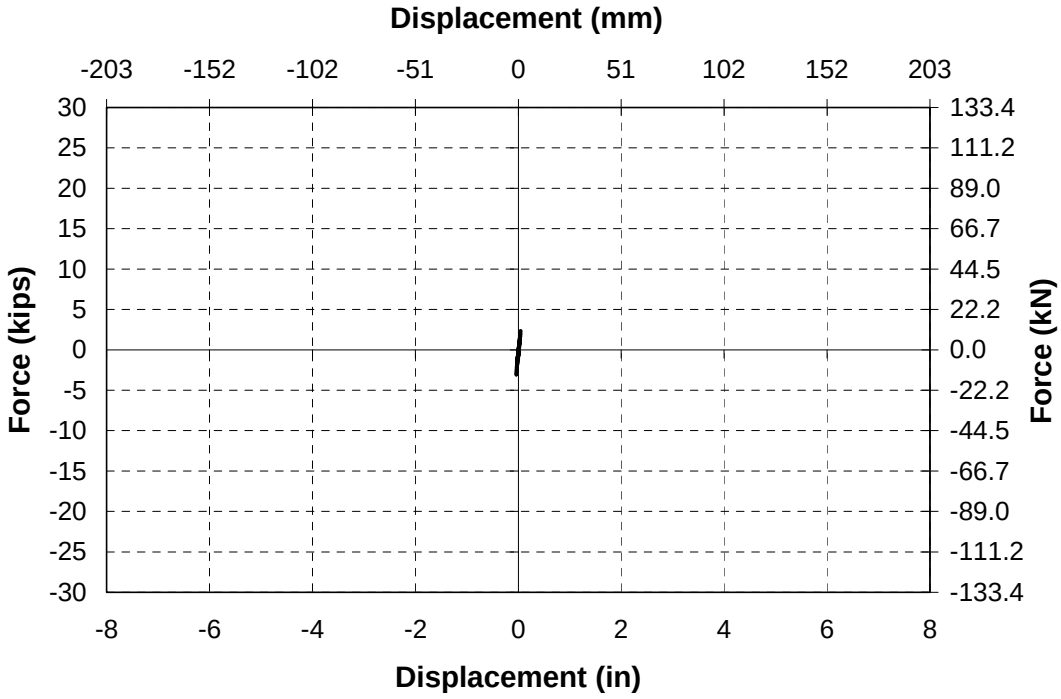


Fig. 3-207. Force-Displacement Hysteresis Curve for Run 1 in RC-ECC Column

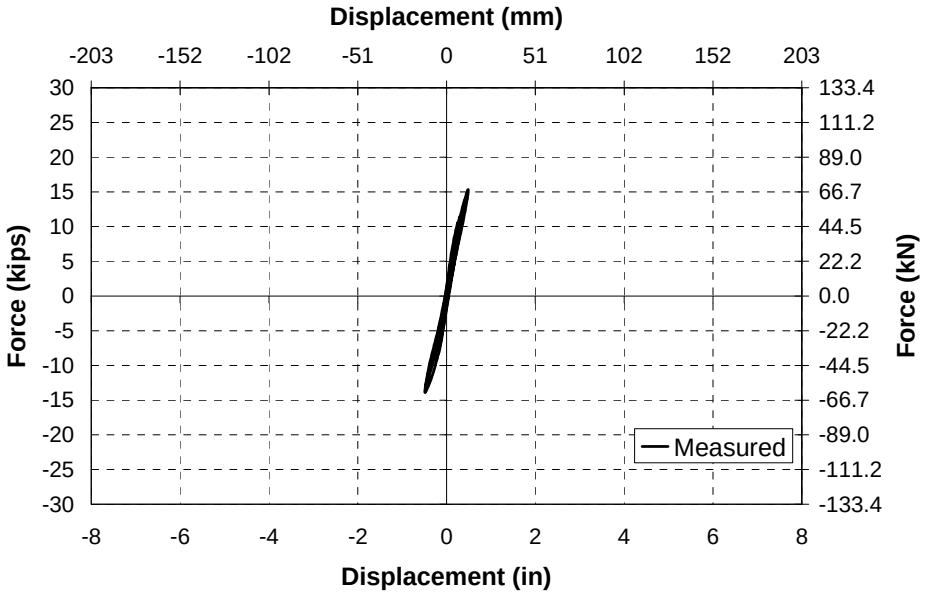


Fig. 3-208. Force-Displacement Hysteresis Curve for Run 2 in RC-ECC Column

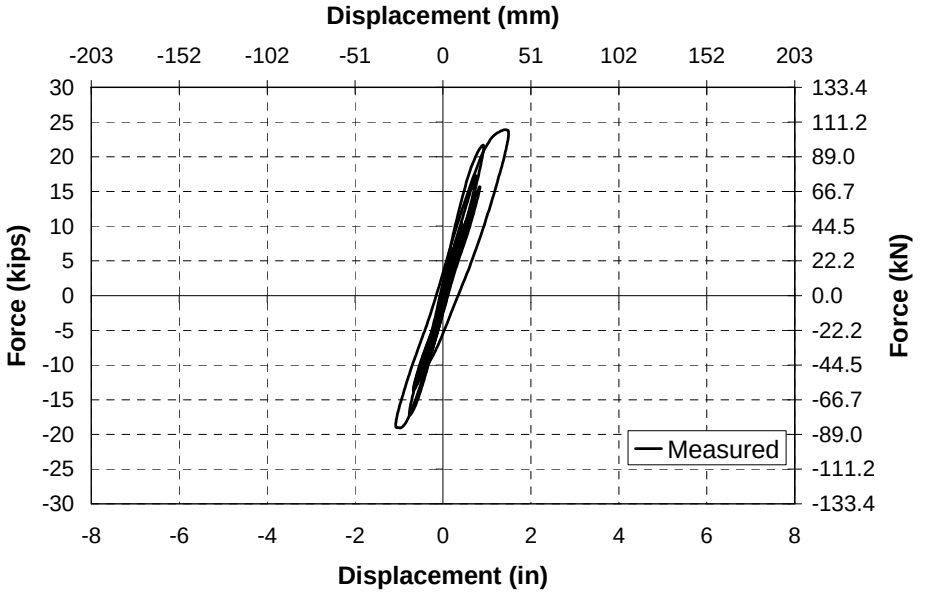


Fig. 3-209. Force-Displacement Hysteresis Curve for Run 3 in RC-ECC Column

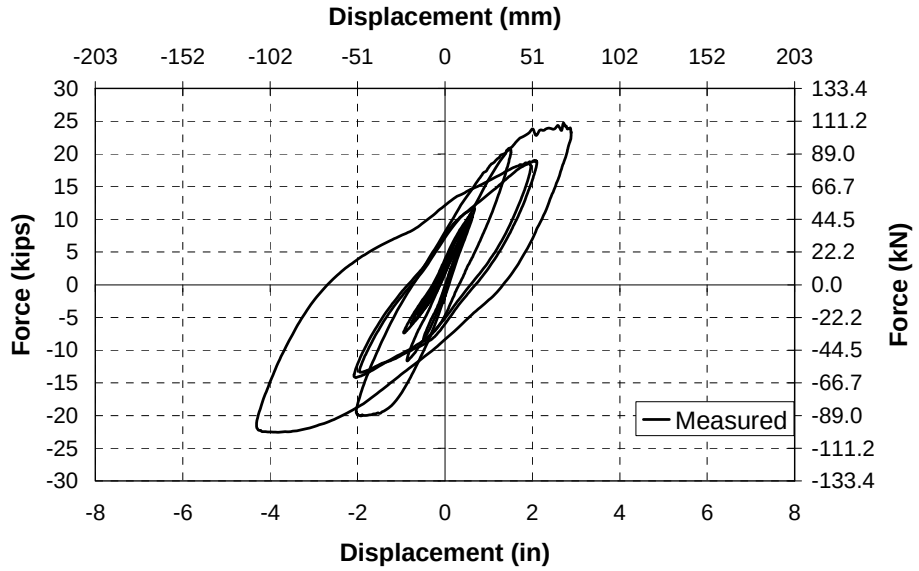


Fig. 3-210. Force-Displacement Hysteresis Curve for Run 4 in RC-ECC Column

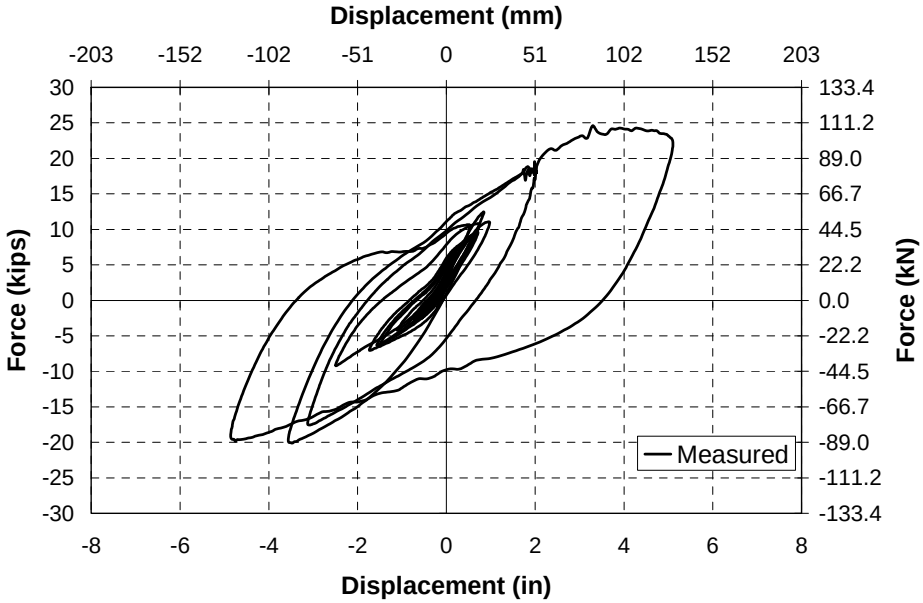


Fig. 3-211. Force-Displacement Hysteresis Curve for Run 5 in RC-ECC Column

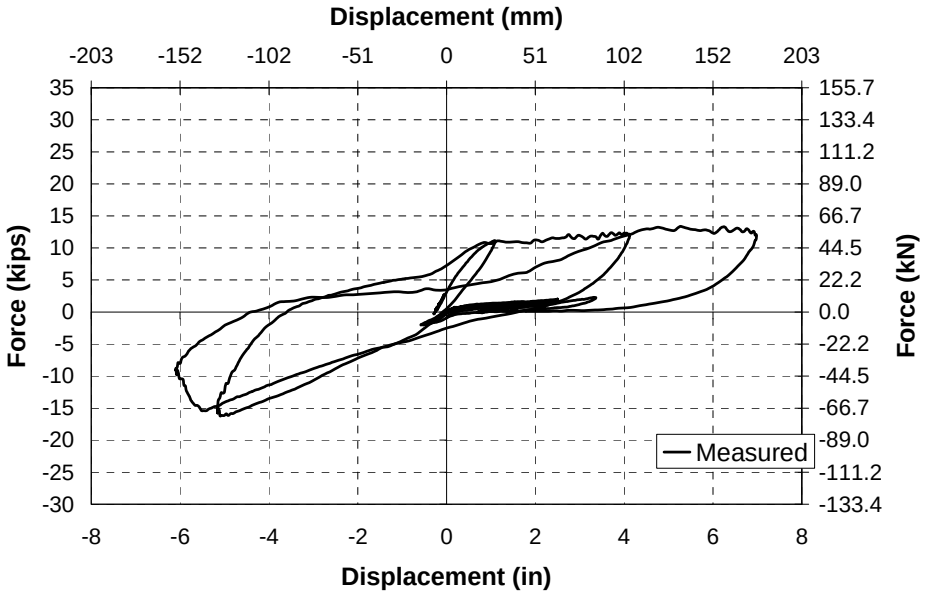


Fig. 3-212. Force-Displacement Hysteresis Curve for Run 6 in RC-ECC Column

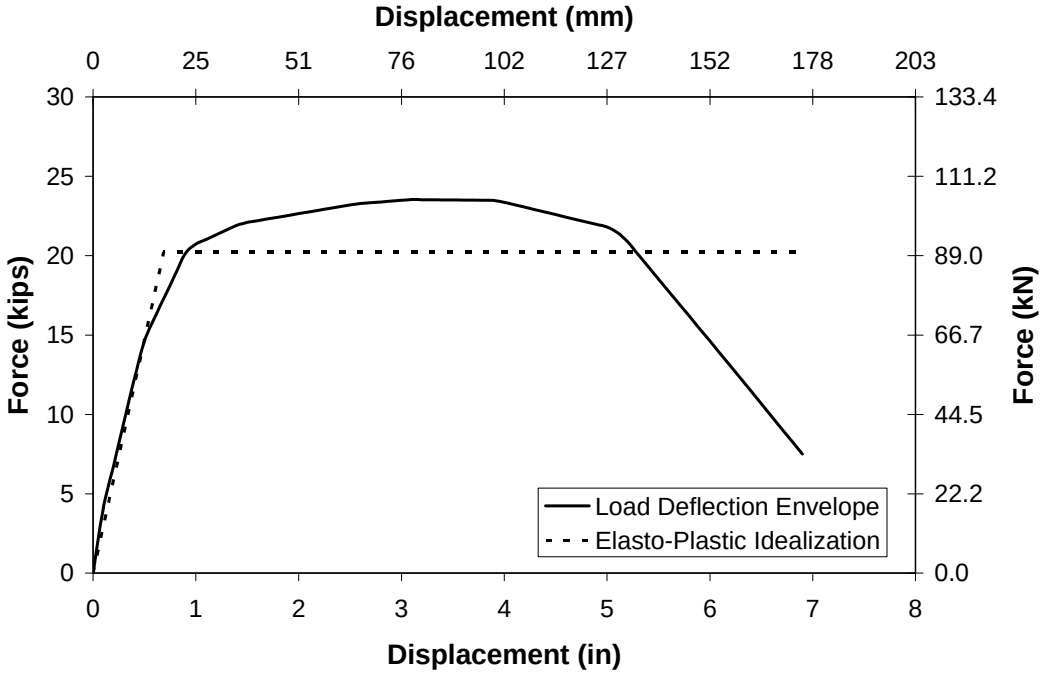


Fig. 3-213. Backbone Curve of RC-ECC Column

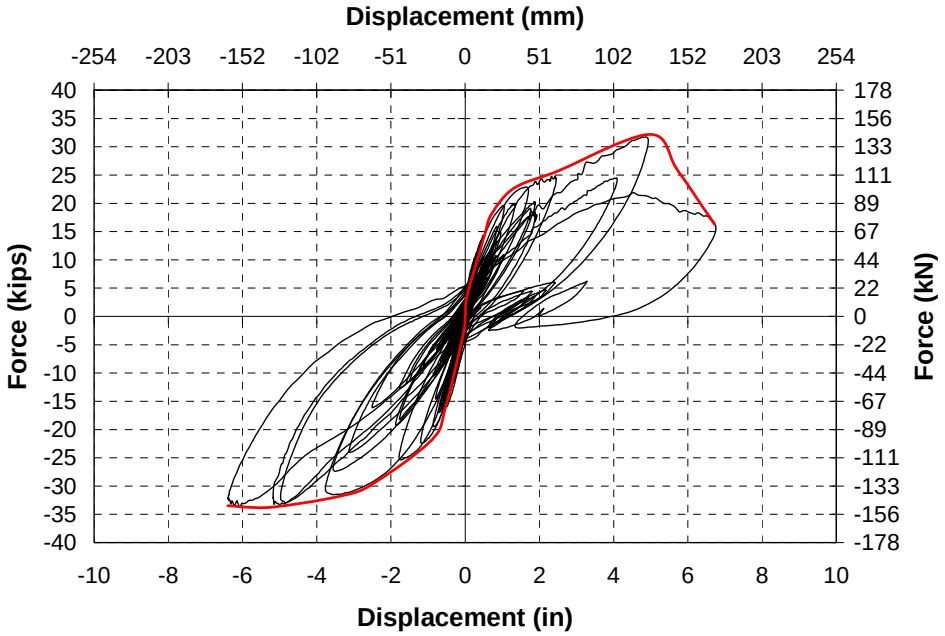


Fig. 3-214. Accumulated Force-Displacement Hysteresis Curve for FRP Column

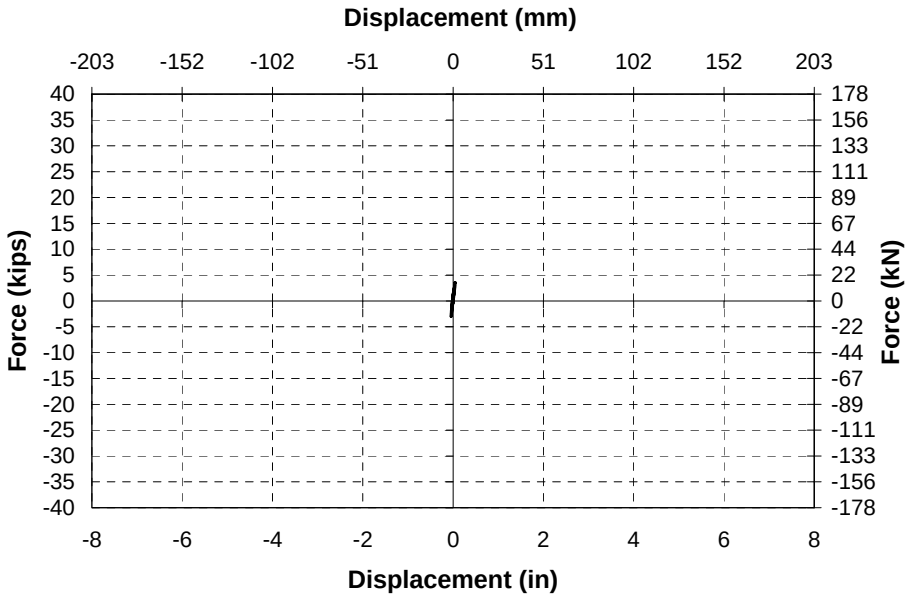


Fig. 3-215. Force-Displacement Hysteresis Curve for Run 1 in FRP Column

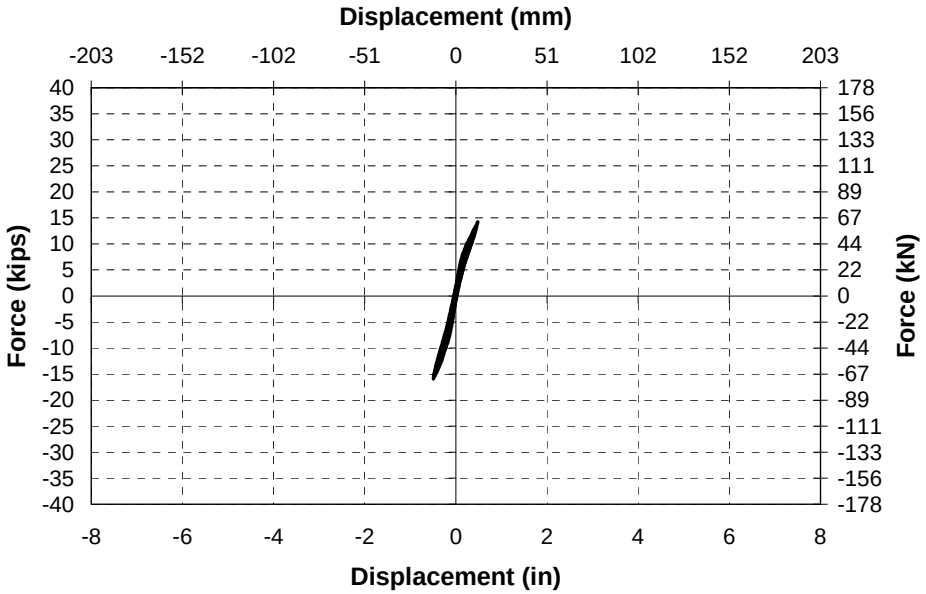


Fig. 3-216. Force-Displacement Hysteresis Curve for Run 2 in FRP Column

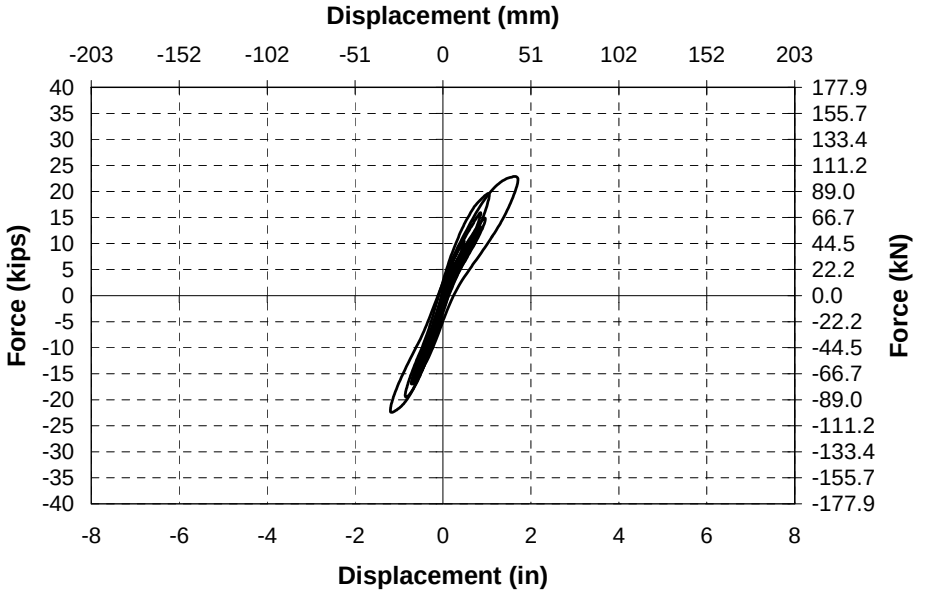


Fig. 3-217. Force-Displacement Hysteresis Curve for Run 3 in FRP Column

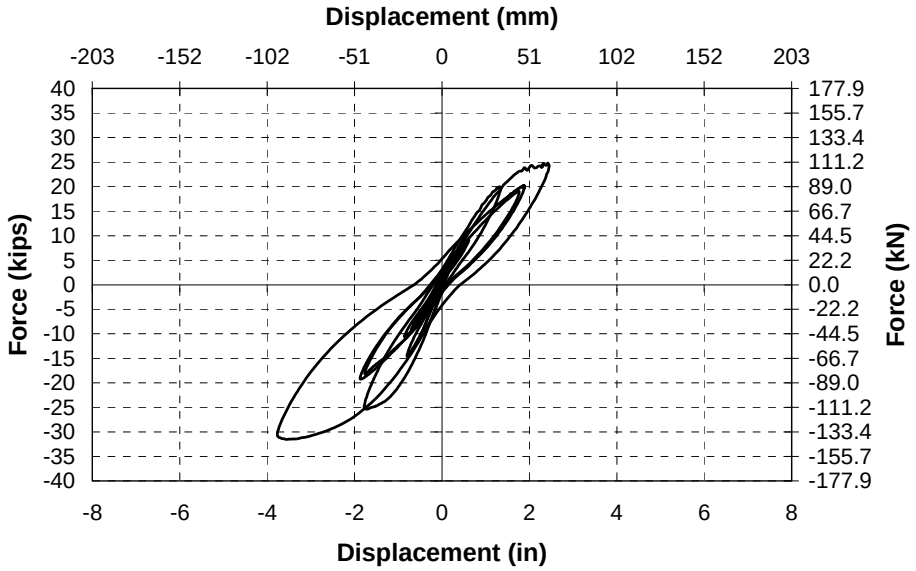


Fig. 3-218. Force-Displacement Hysteresis Curve for Run 4 in FRP Column

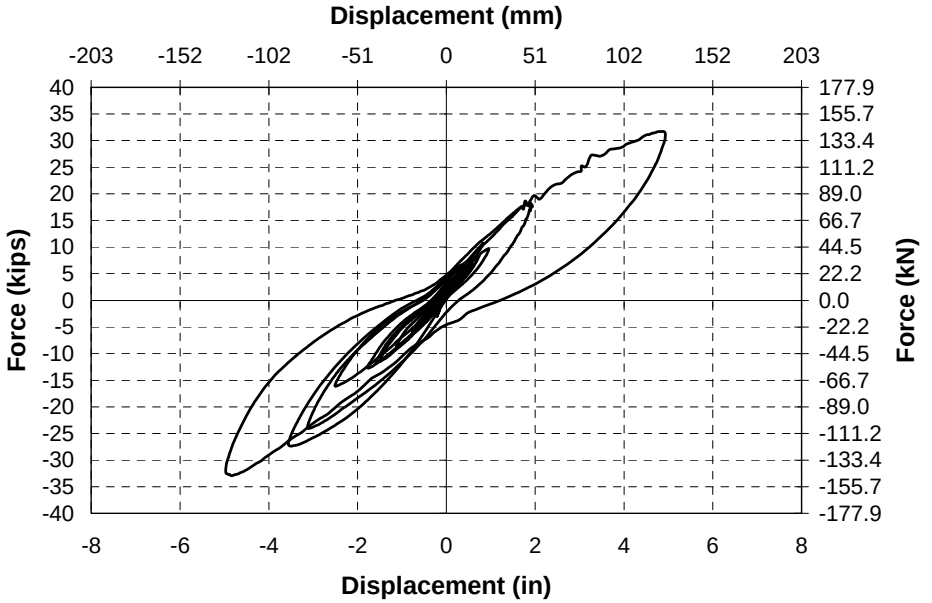


Fig. 3-219. Force-Displacement Hysteresis Curve for Run 5 in FRP Column

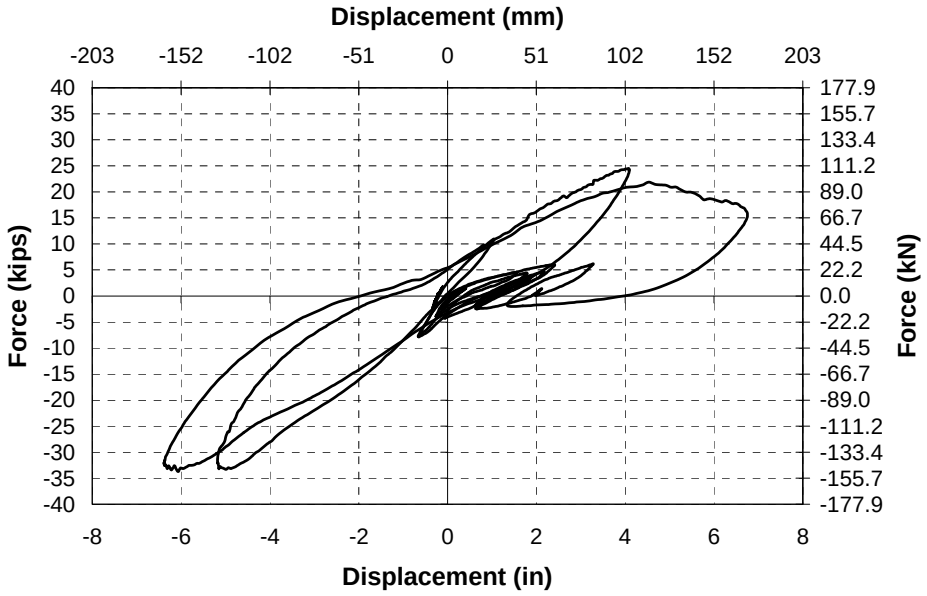


Fig. 3-220. Force-Displacement Hysteresis Curve for Run 6 in FRP Column

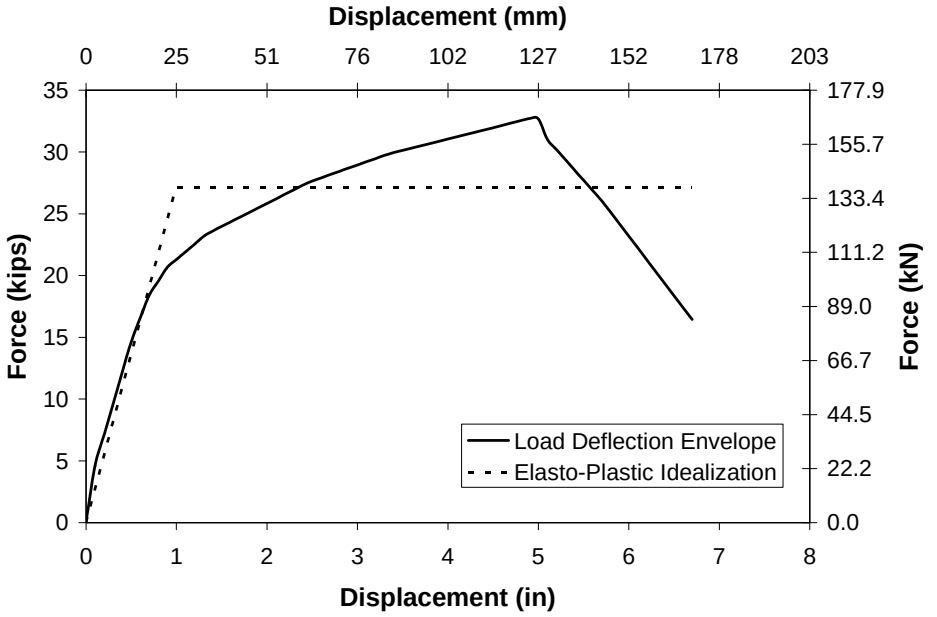


Fig. 3-221. Backbone Curve of FRP Column

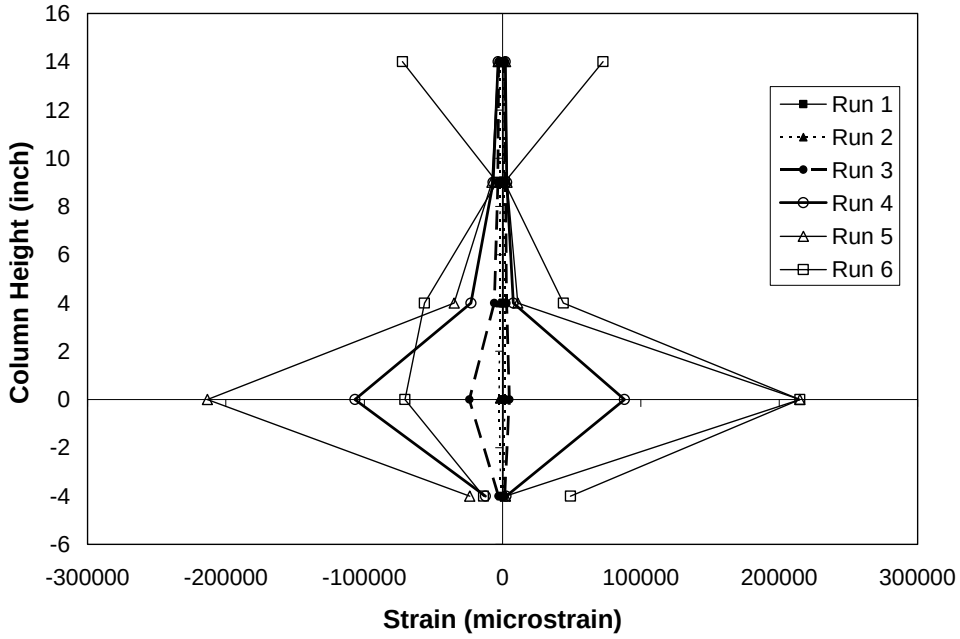


Fig. 3-222. The Max. and Min. Long. Strain Profile of the RC-ECC Column

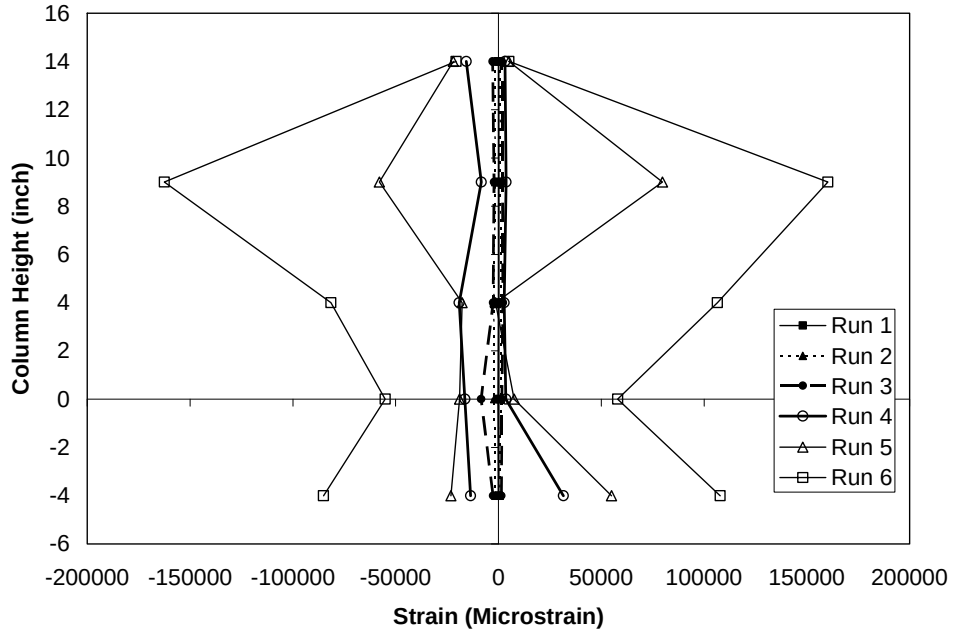


Fig. 3-223. The Max. and Min. Long. Strain Profile of the FRP Column

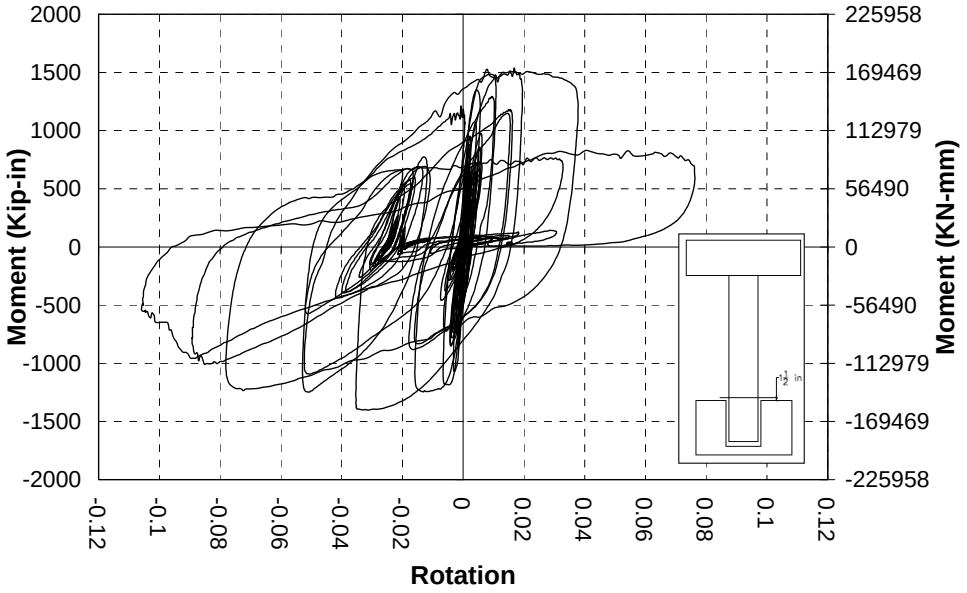


Fig. 3-224. Bond-Slip Rotation of RC-ECC Column

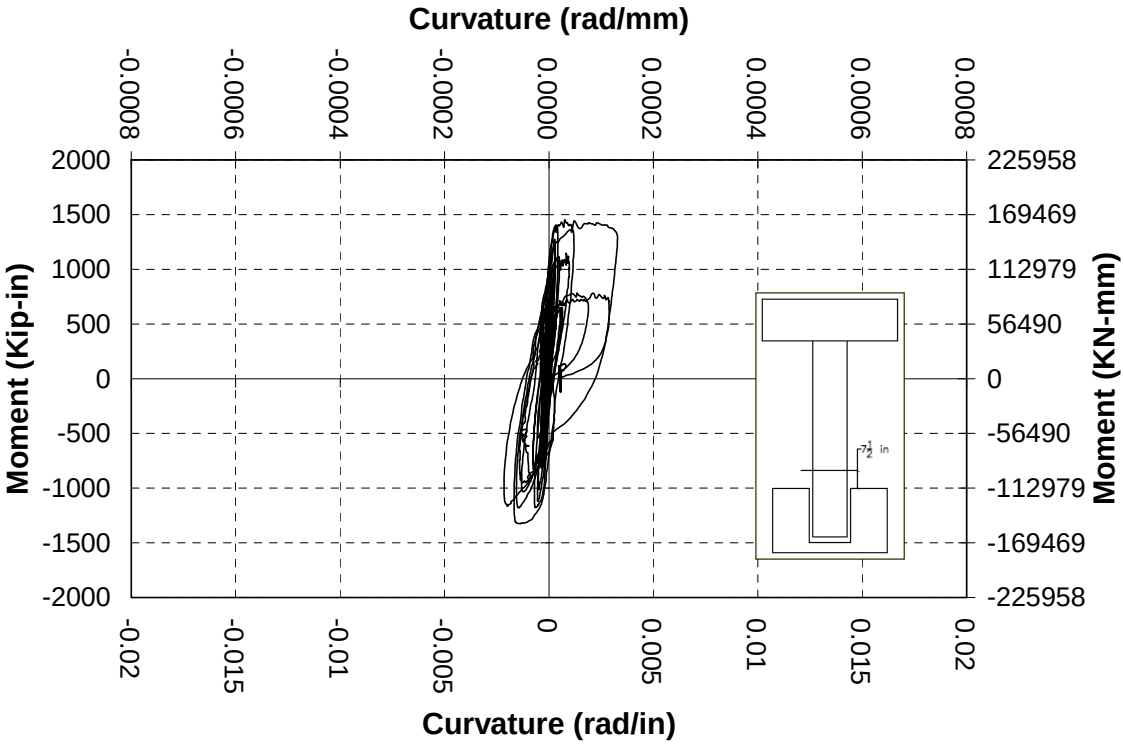


Fig. 3-225. Accumulated Moment Curvature at the First Level in RC-ECC Column

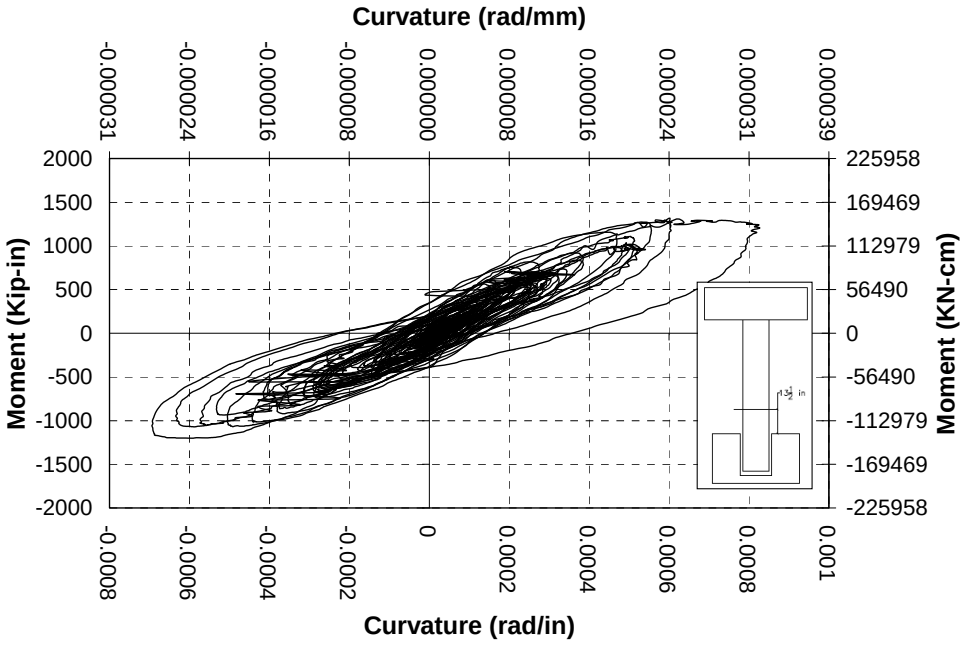


Fig. 3-226. Accumulated Moment Curvature at the Second Level in RC-ECC Column

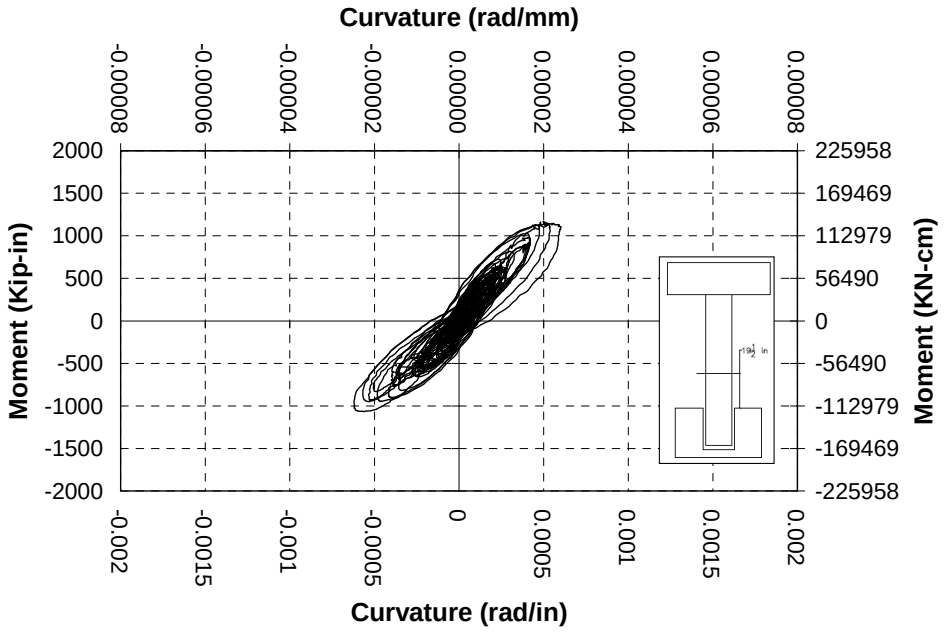


Fig. 3-227. Accumulated Moment Curvature at the Third Level in RC-ECC Column

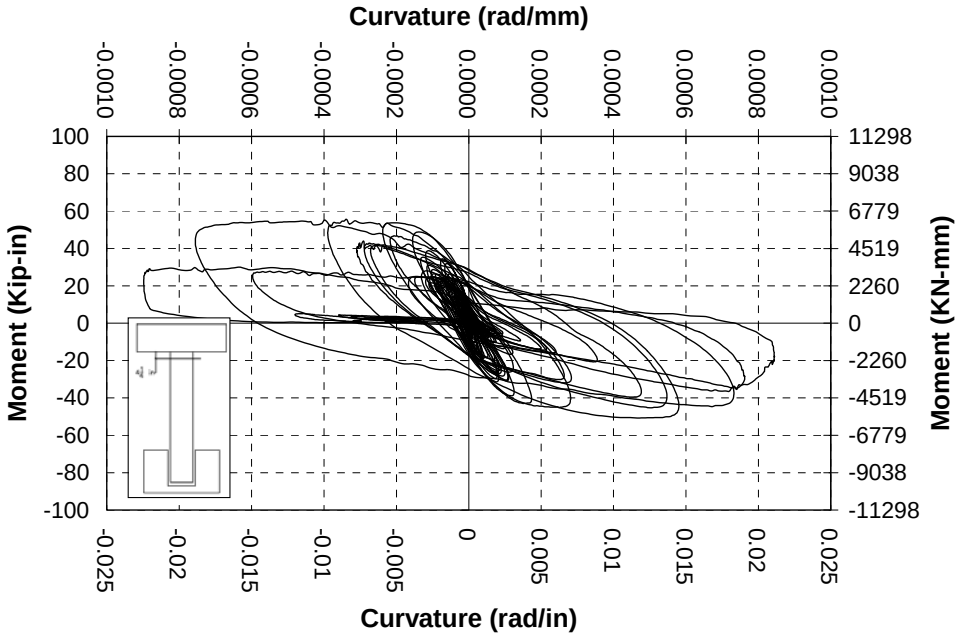


Fig. 3-228. Accumulated Moment Curvature at the Fourth Level in RC-ECC Column

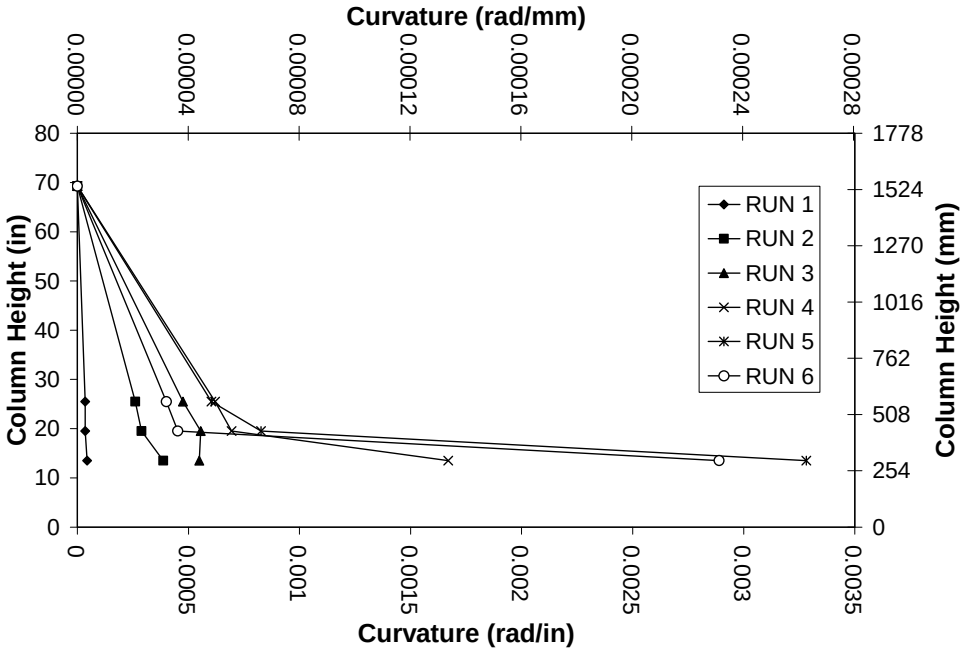


Fig. 3-229. Curvature Profile for RC-ECC Column

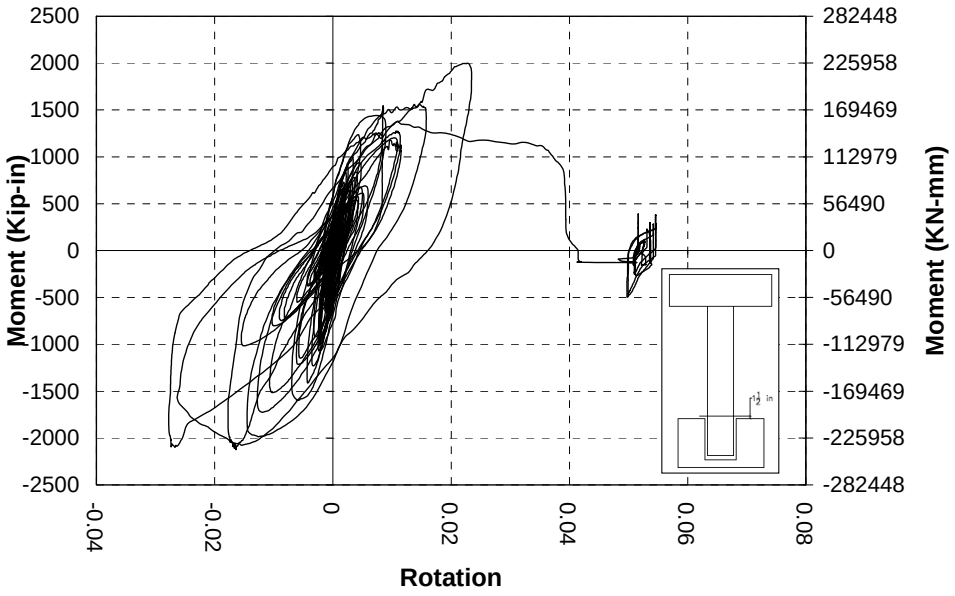


Fig. 3-230. Base Rotation of the FRP Column

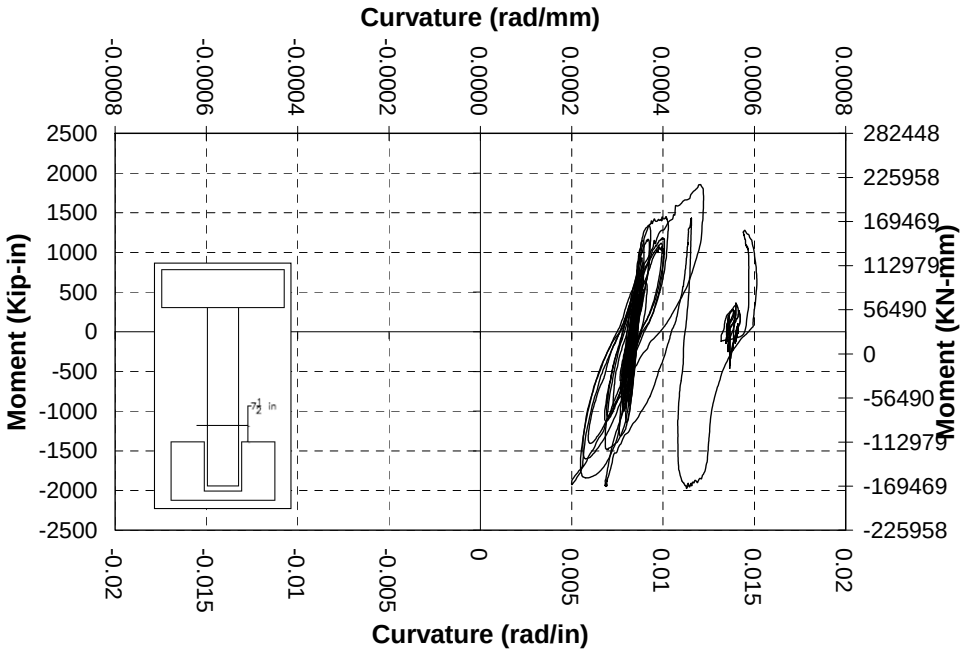


Fig. 3-231. Accumulated Moment Curvature at the First Level in FRP Column