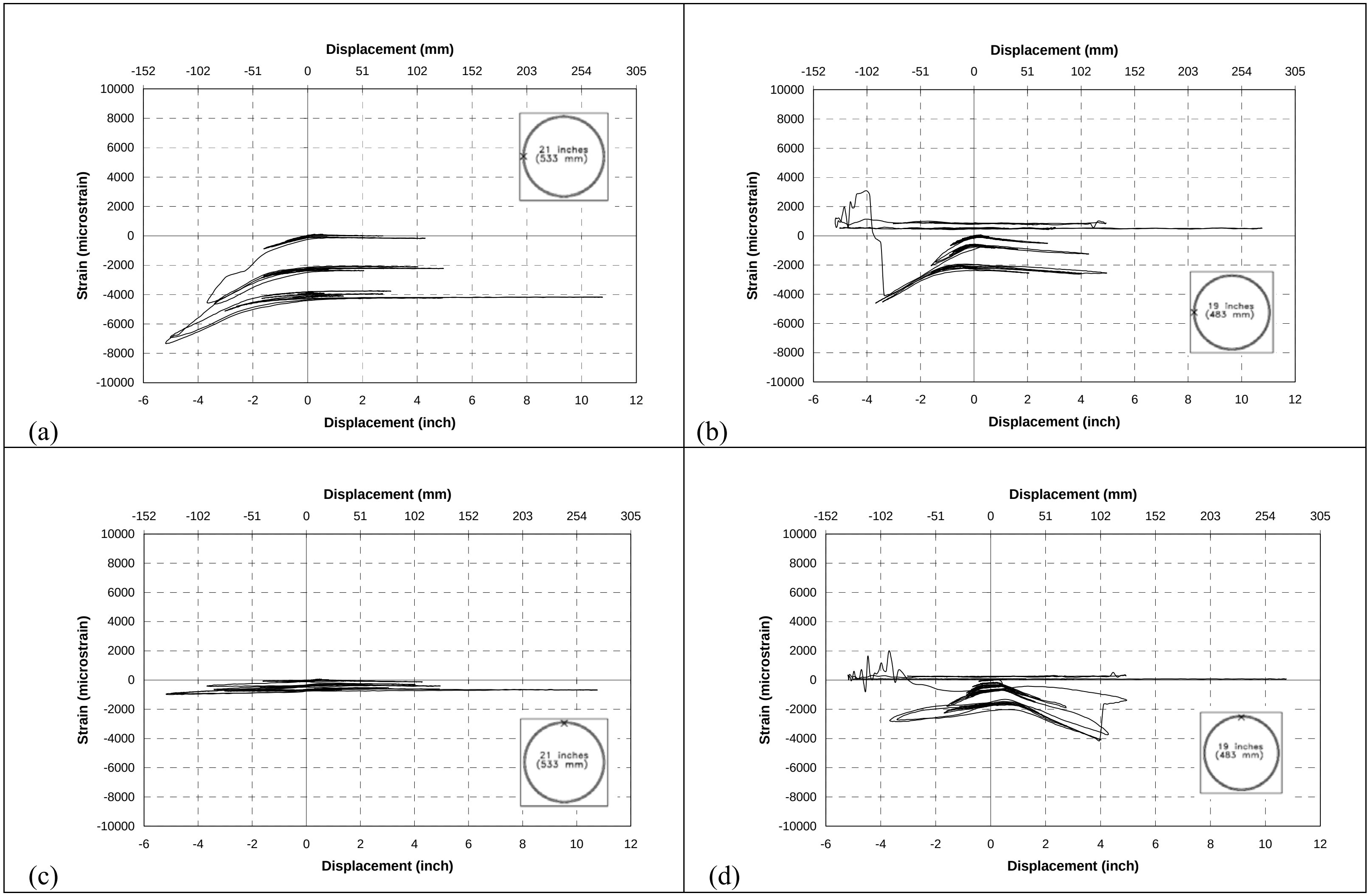

Fig. A-47. a) sg 67, b) sg 68, c) sg 69, d) sg 70 in SF-2(on the FRP Wrap)

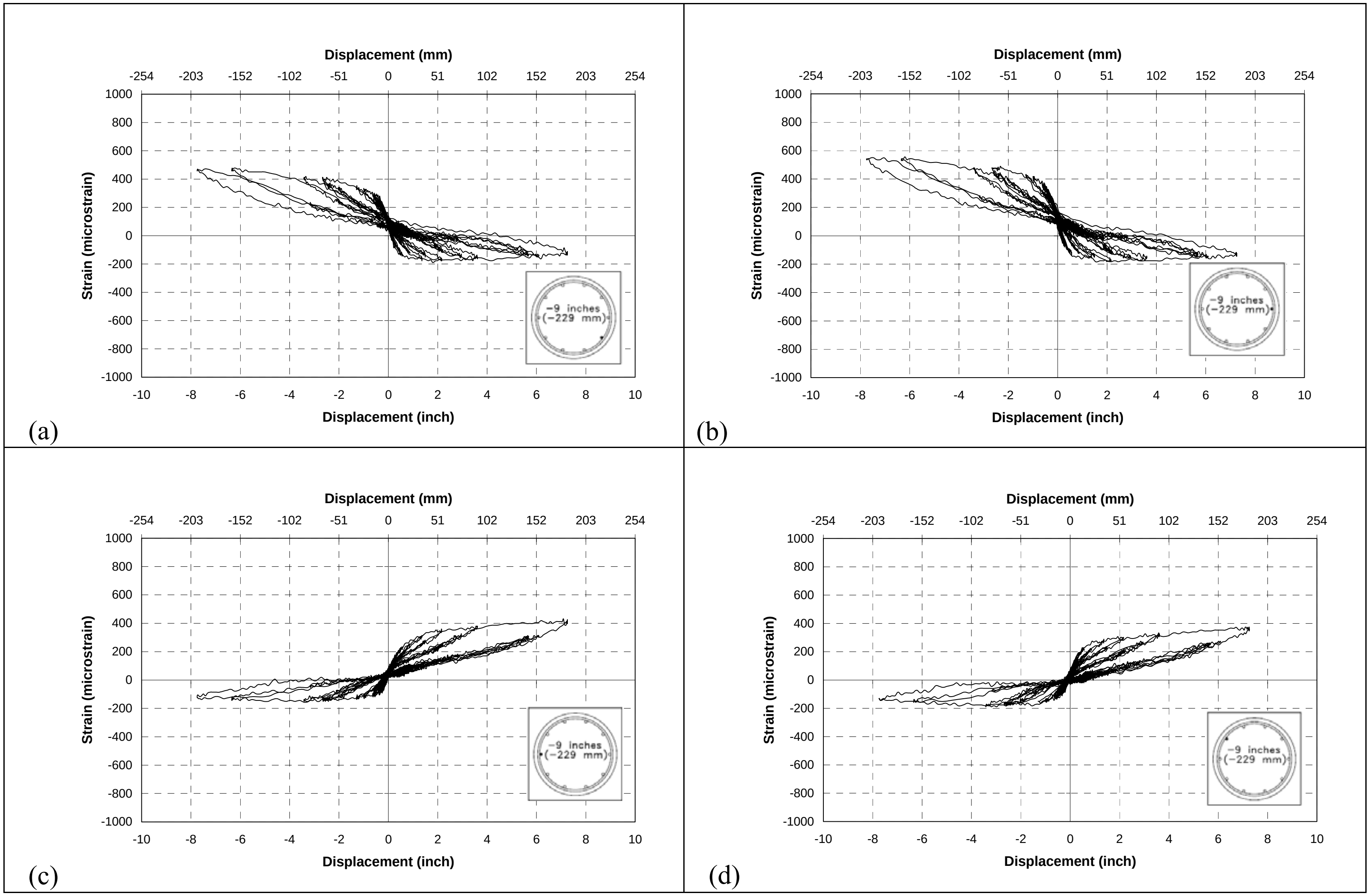

Fig. A-48. a) sg 1, b) sg 2, c) sg 3, d) sg 4 in SE-2

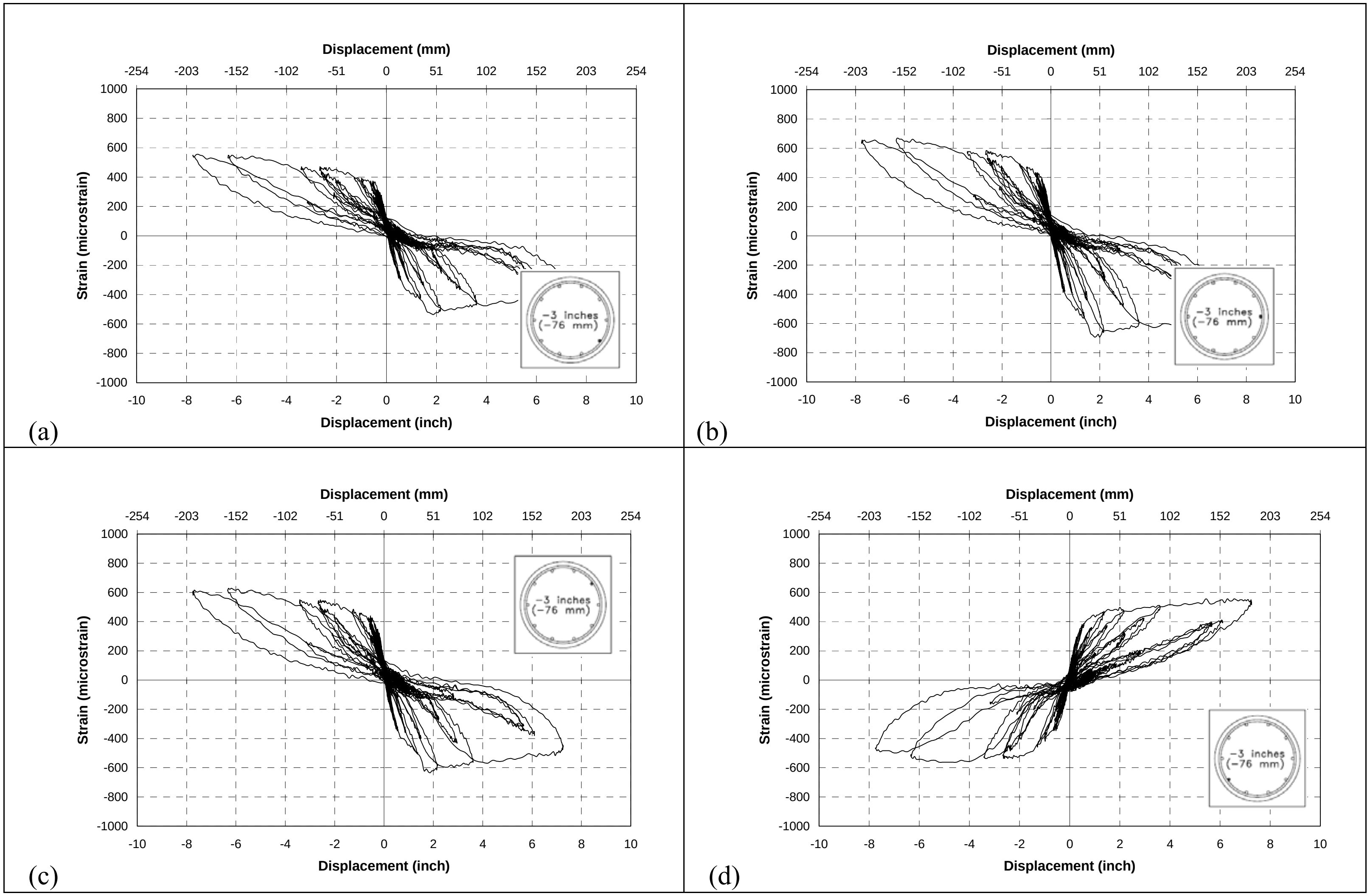

Fig. A-49. a) sg 5, b) sg 6, c) sg 7, d) sg 8 in SE-2

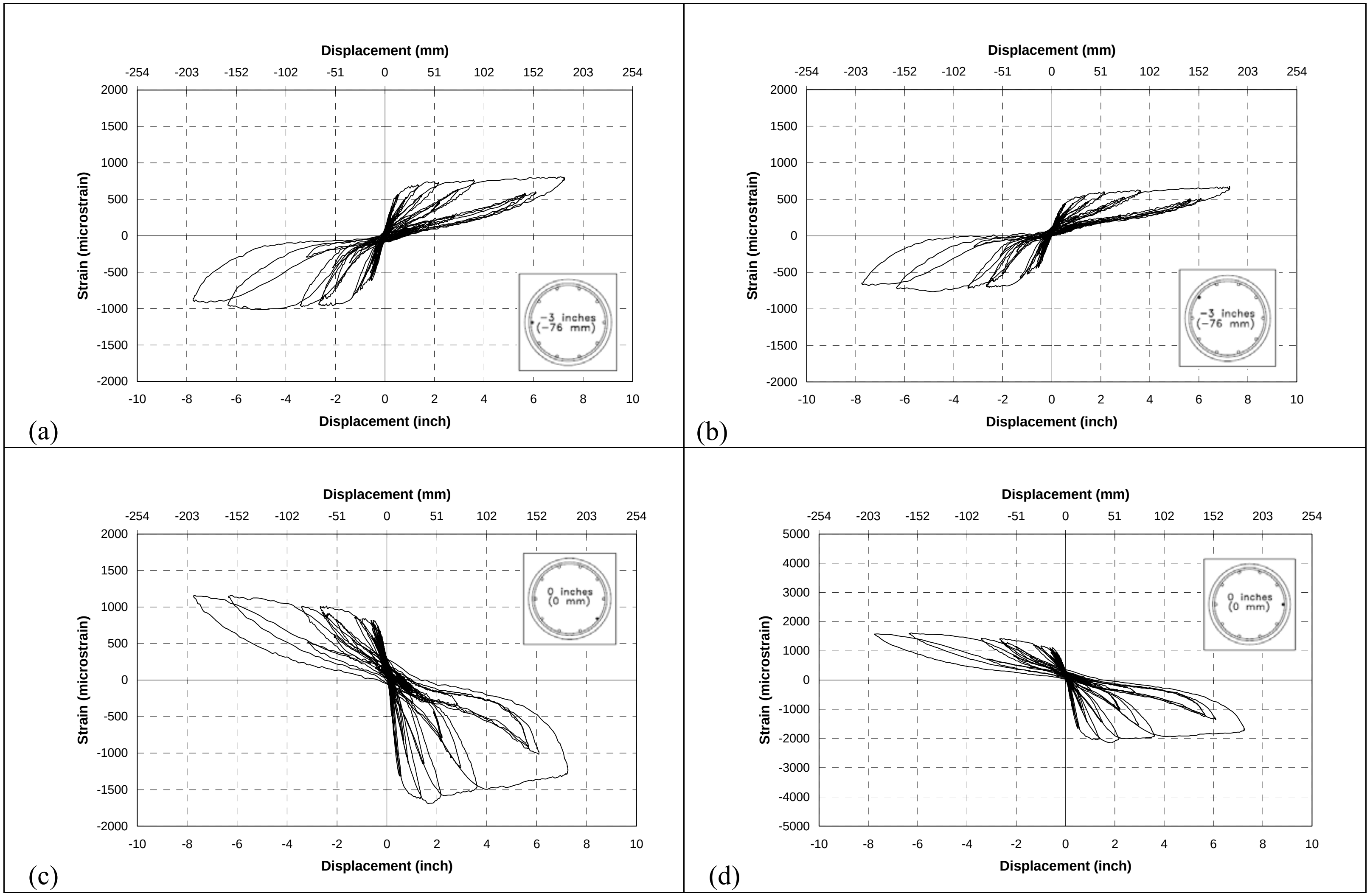

Fig. A-50. a) sg 9, b) sg 10, c) sg 11, d) sg 12 in SE-2

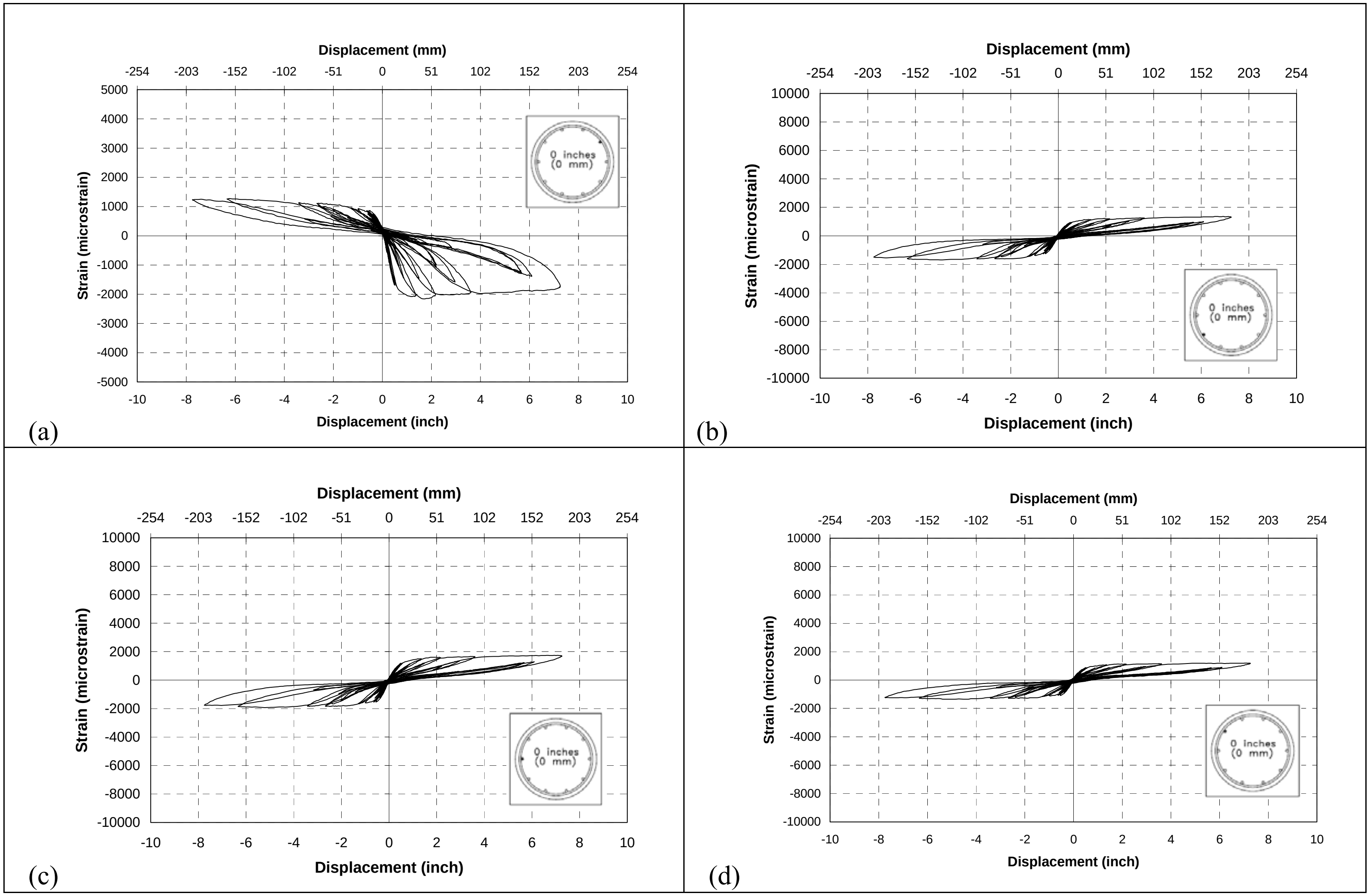

Fig. A-51. a) sg 1,3 b) sg 14, c) sg 15, d) sg 16 in SE-2

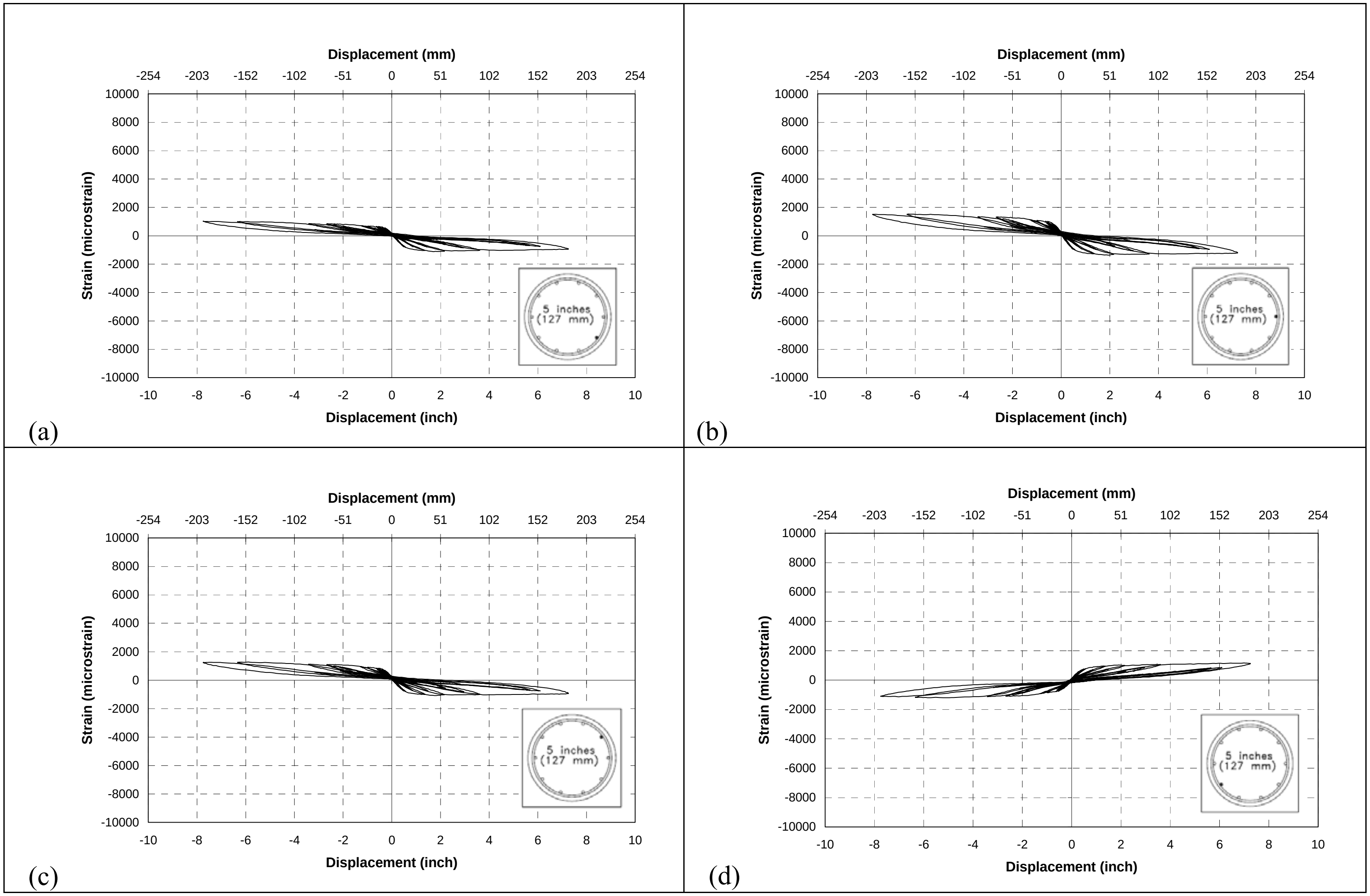

Fig. A-52. a) sg 17, b) sg 18, c) sg 19, d) sg 20 in SE-2

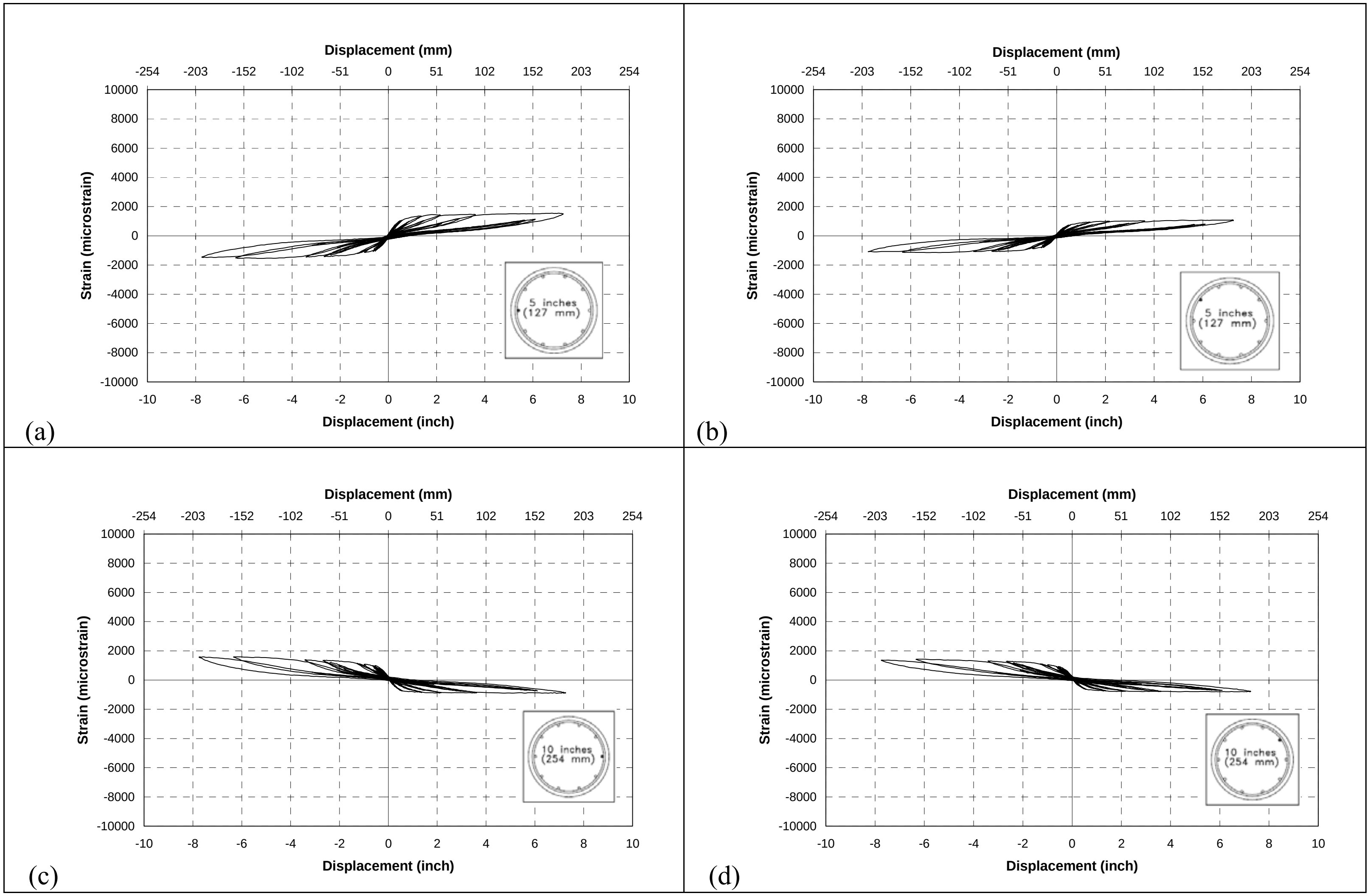

Fig. A-53. a) sg 21, b) sg 22, c) sg 24, d) sg 25 in SE-2

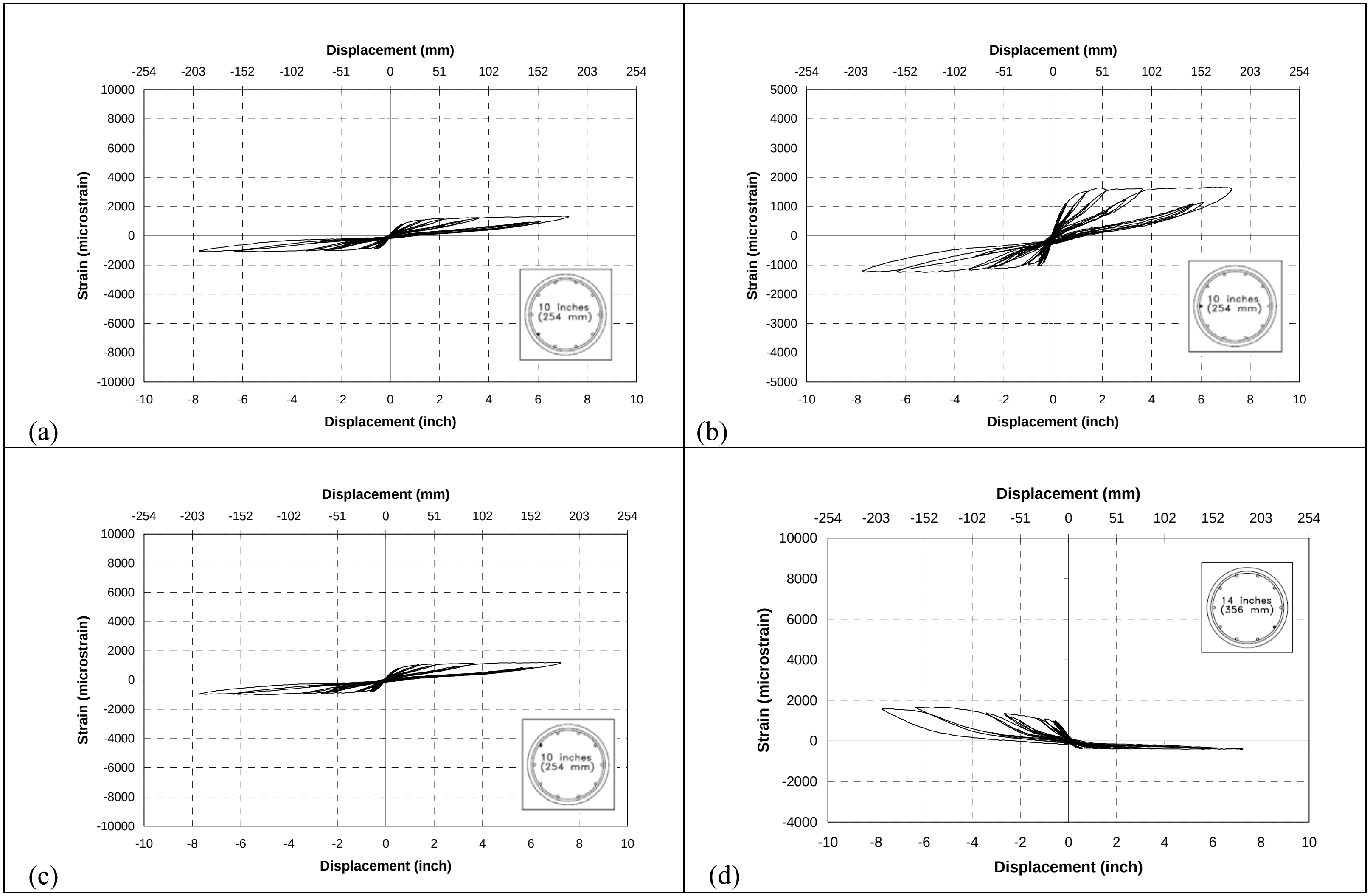

Fig. A-54. a) sg 26, b) sg 27, c) sg 28, d) sg 29 in SE-2

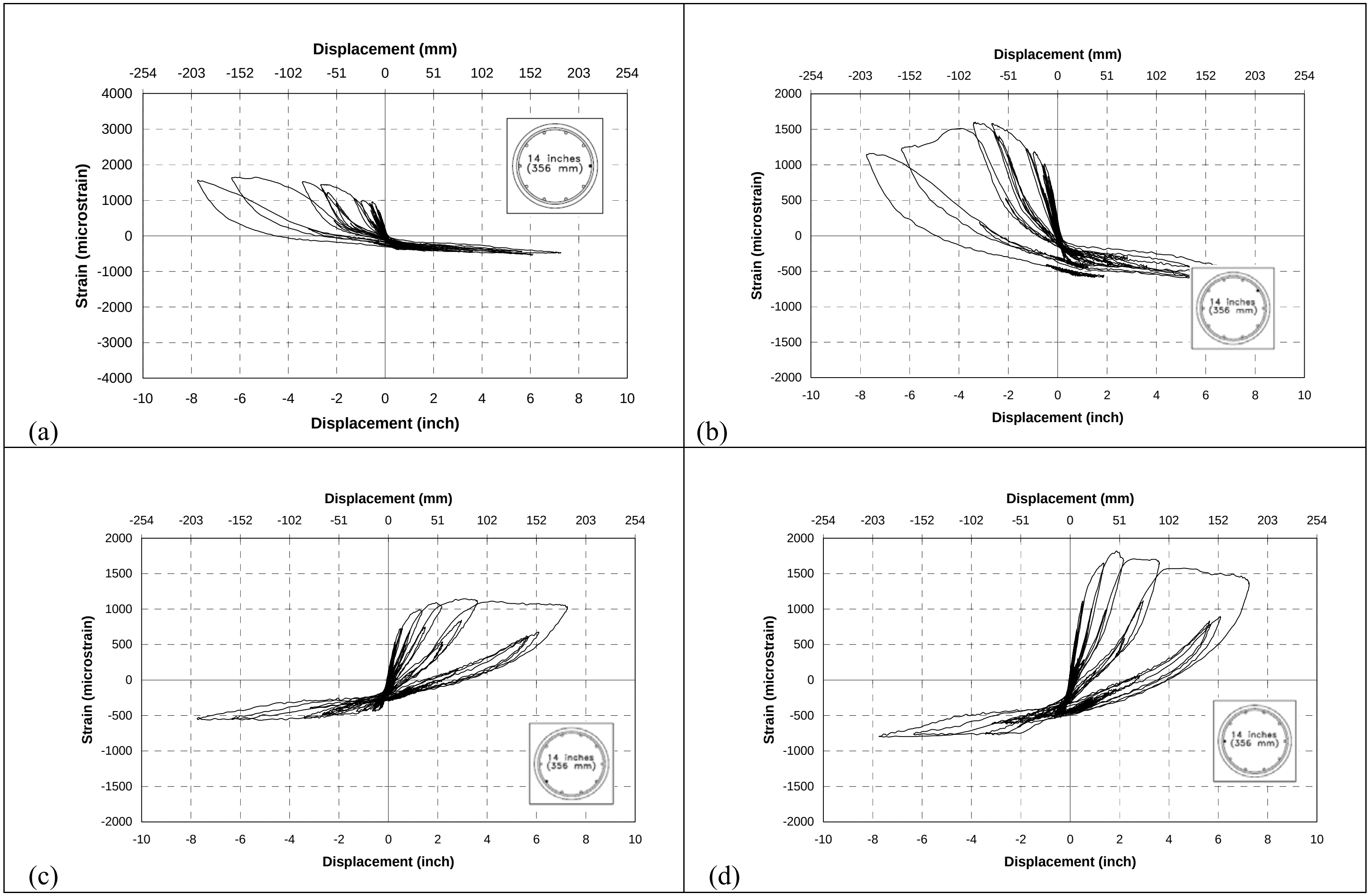

Fig. A-55. a) sg 30, b) sg 31, c) sg 32, d) sg 33 in SE-2

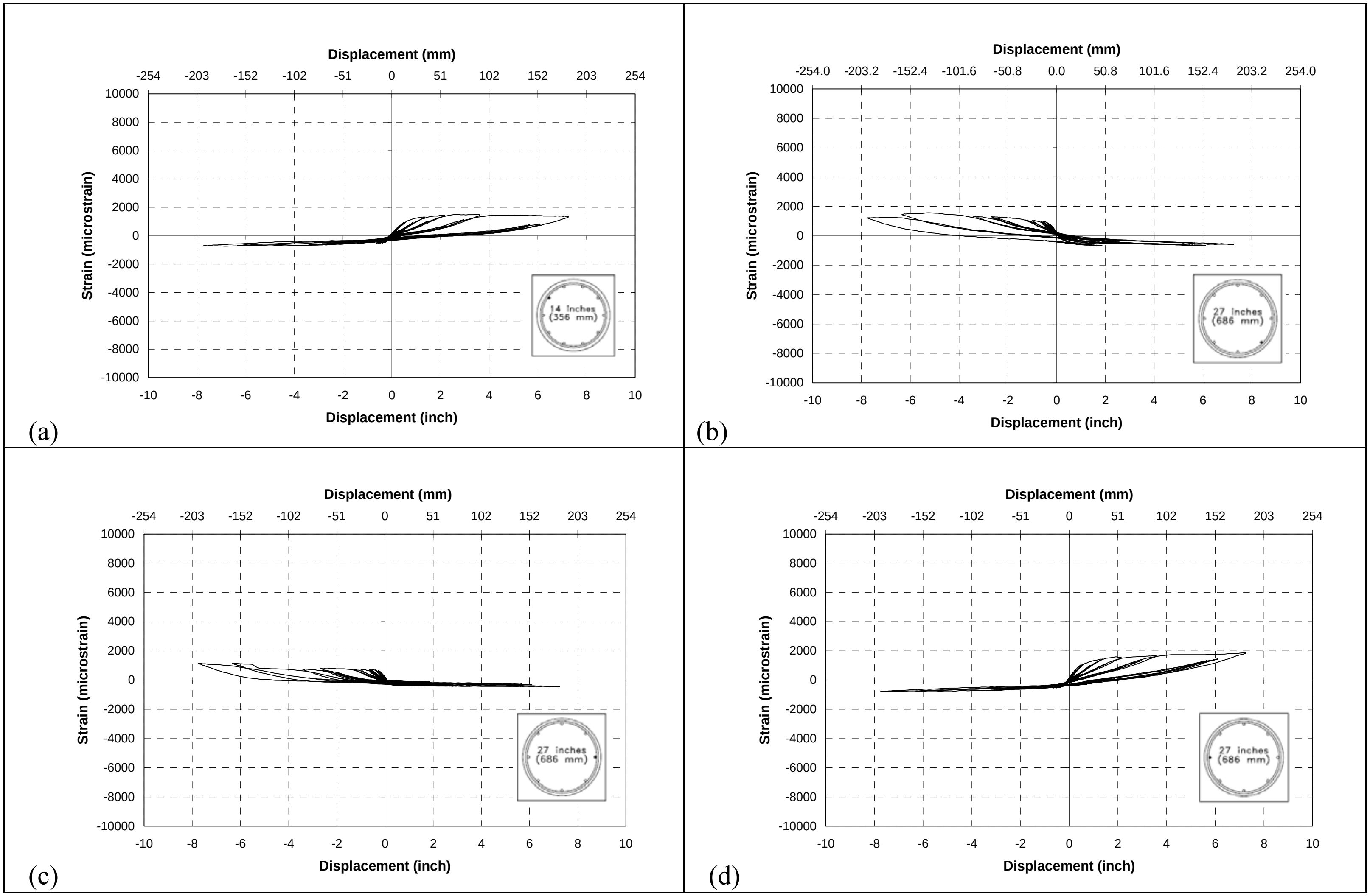

Fig. A-56. a) sg 34, b) sg 35, c) sg 36, d) sg 37 in SE-2

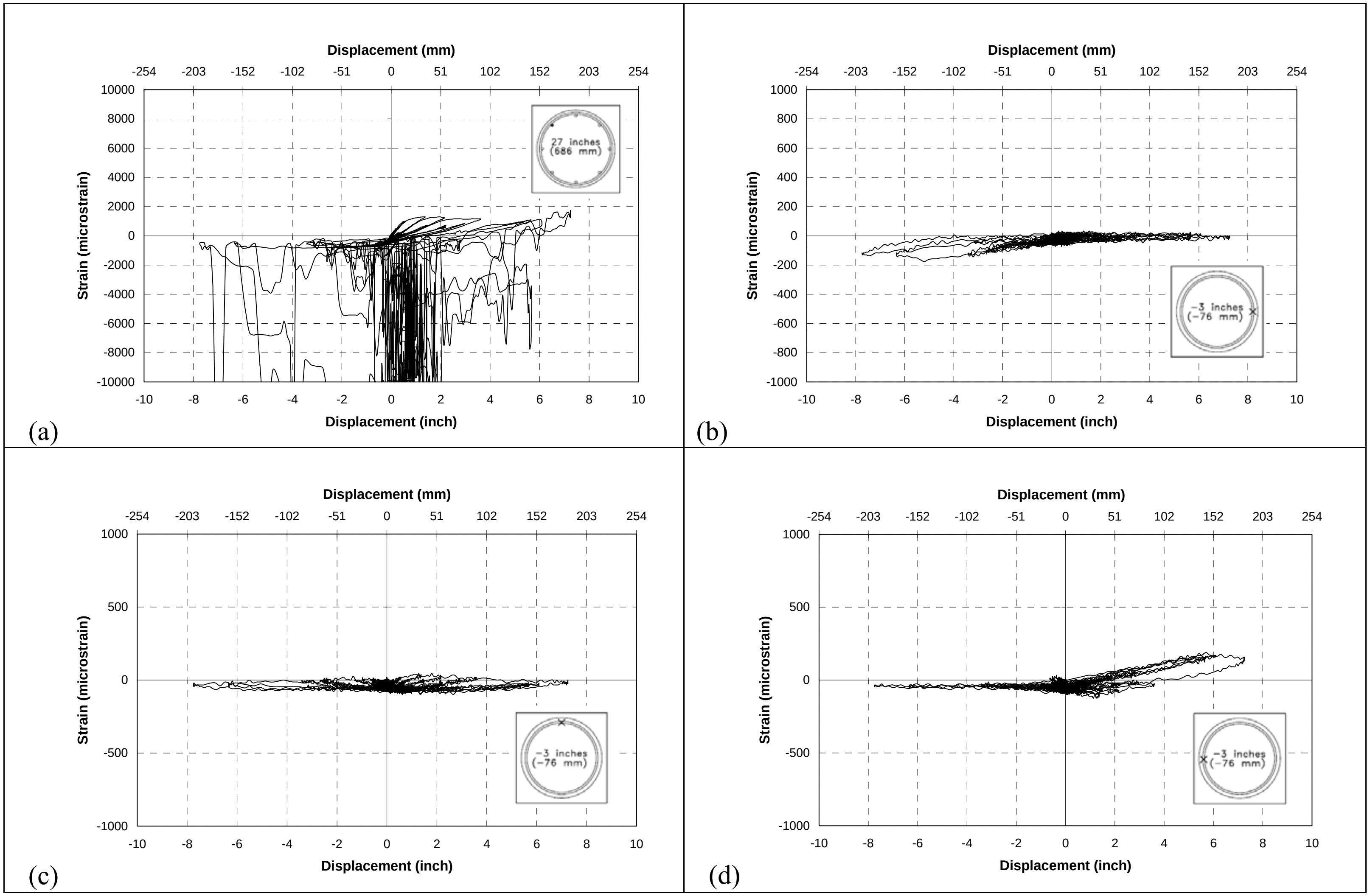

Fig. A-57. a) sg 38, b) sg 40, c) sg 41, d) sg 42 in SE-2

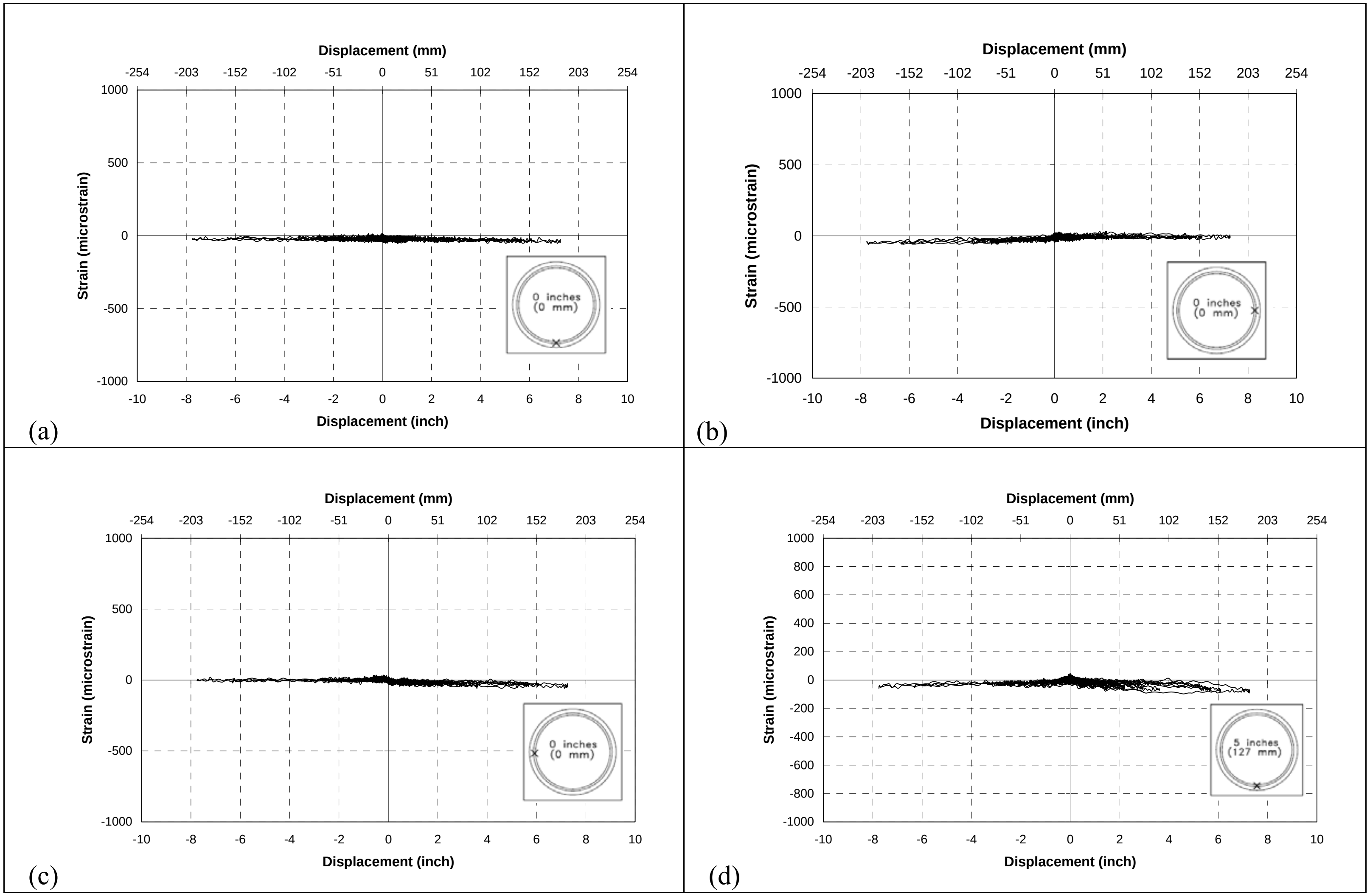

Fig. A-58. a) sg 43, b) sg 44, c) sg 46, d) sg 47 in SE-2

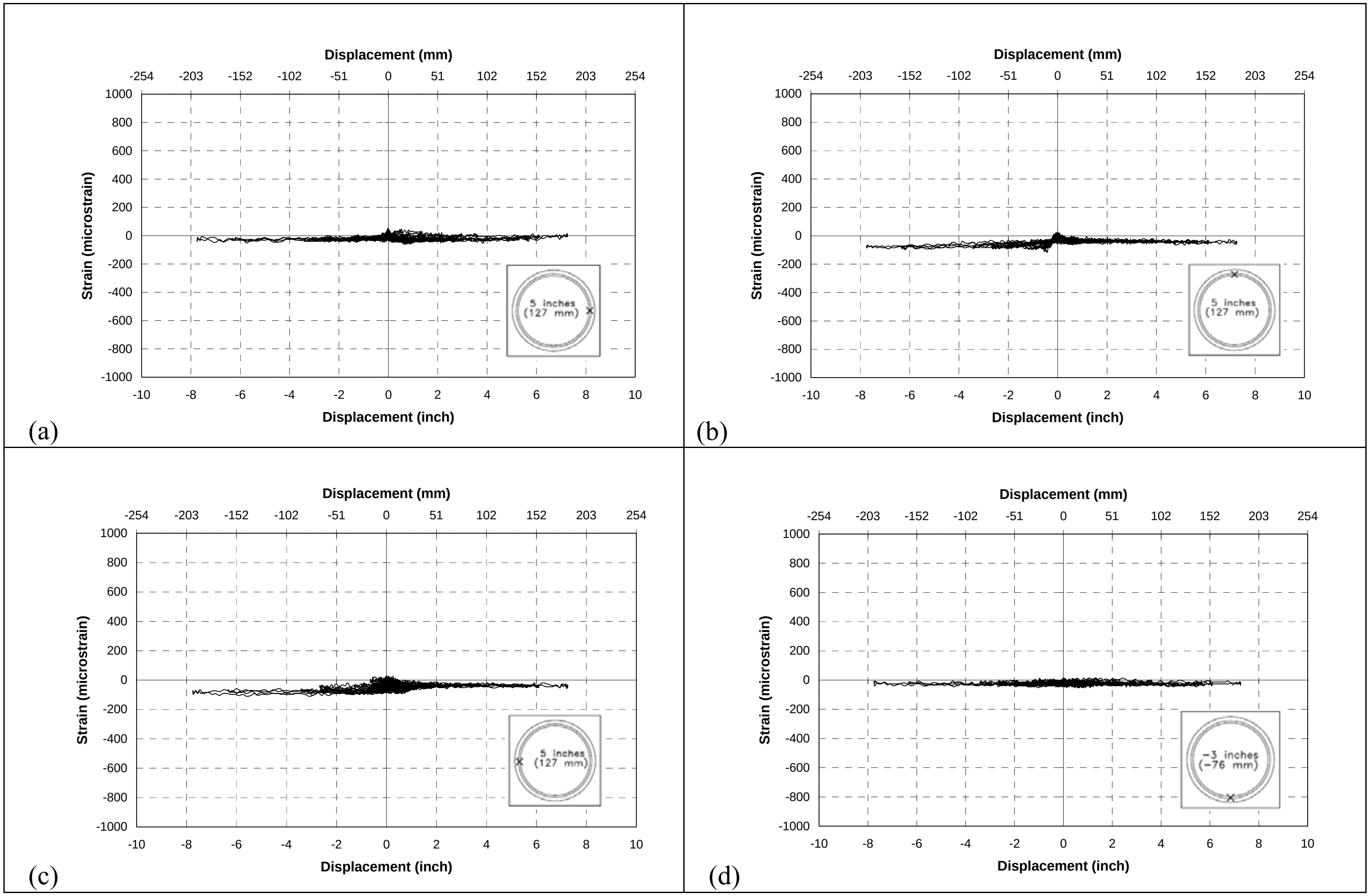

Fig. A-59. a) sg 48, b) sg 49, c) sg 50, d) sg 51 in SE-2

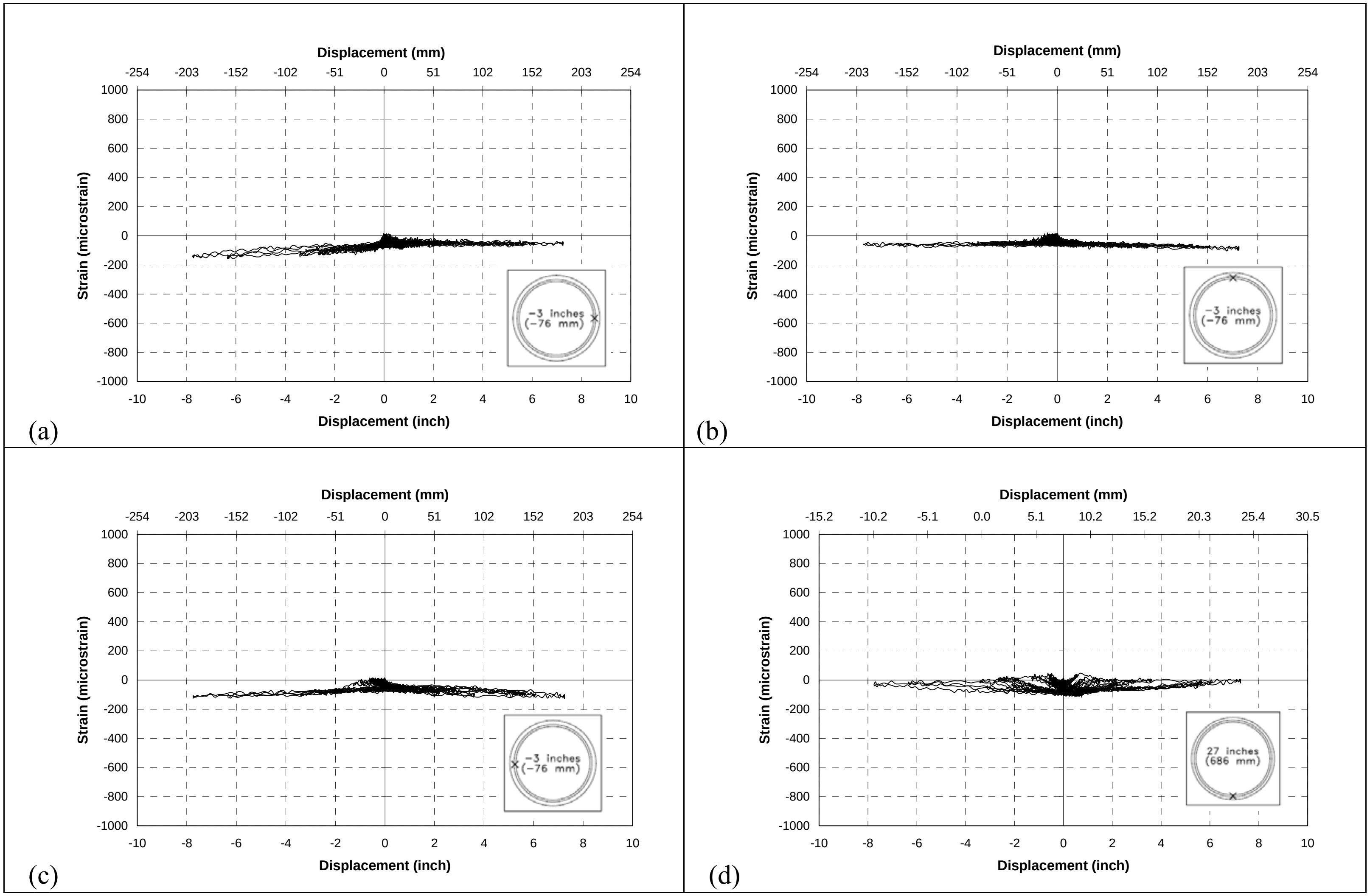

Fig. A-601. a) sg 52, b) sg 53, c) sg 54, d) sg 55 in SE-2

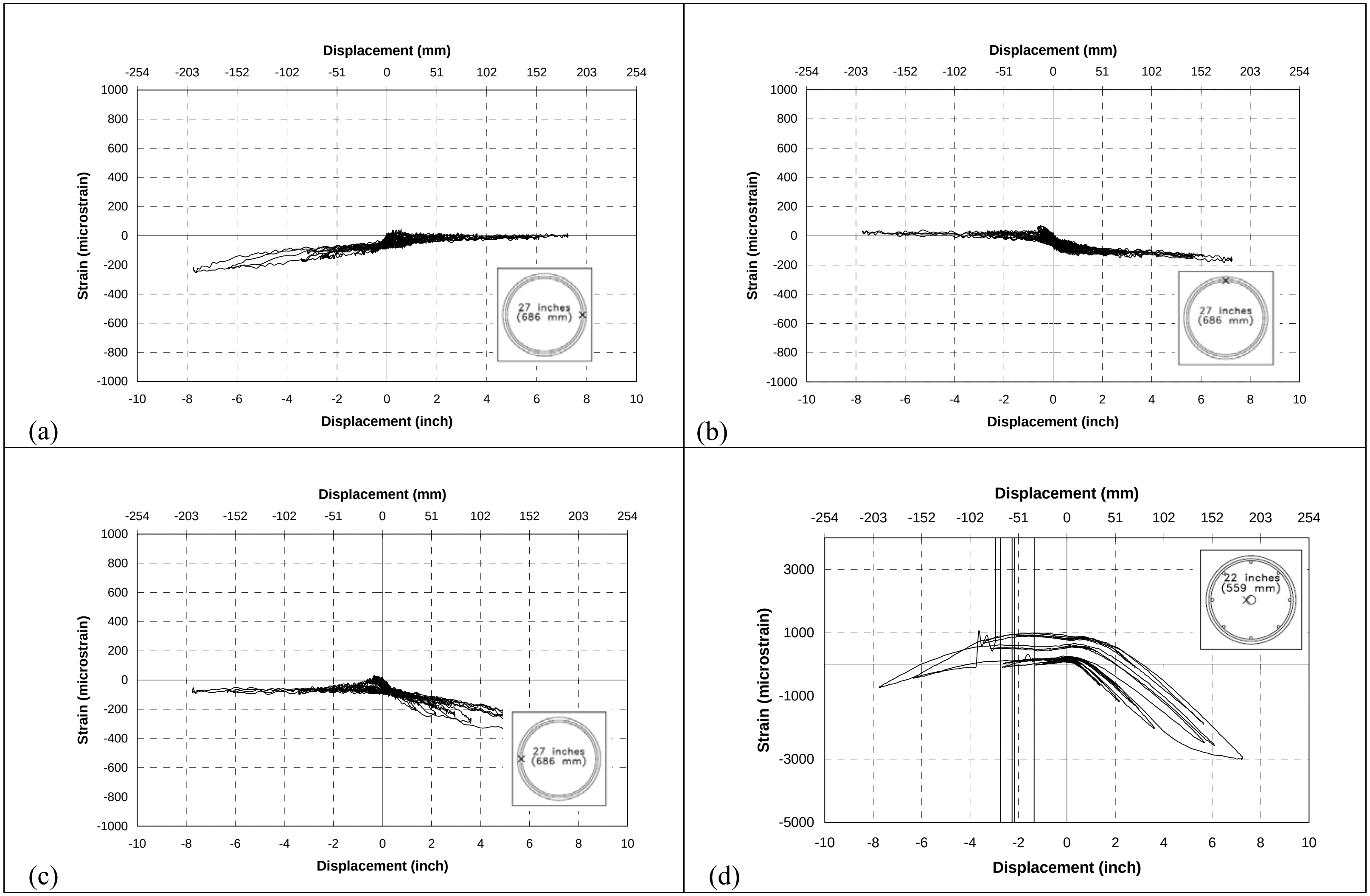

Fig. A-61. a) sg 6 b) sg 57, c) sg 58, d) sg 59 in SE-2

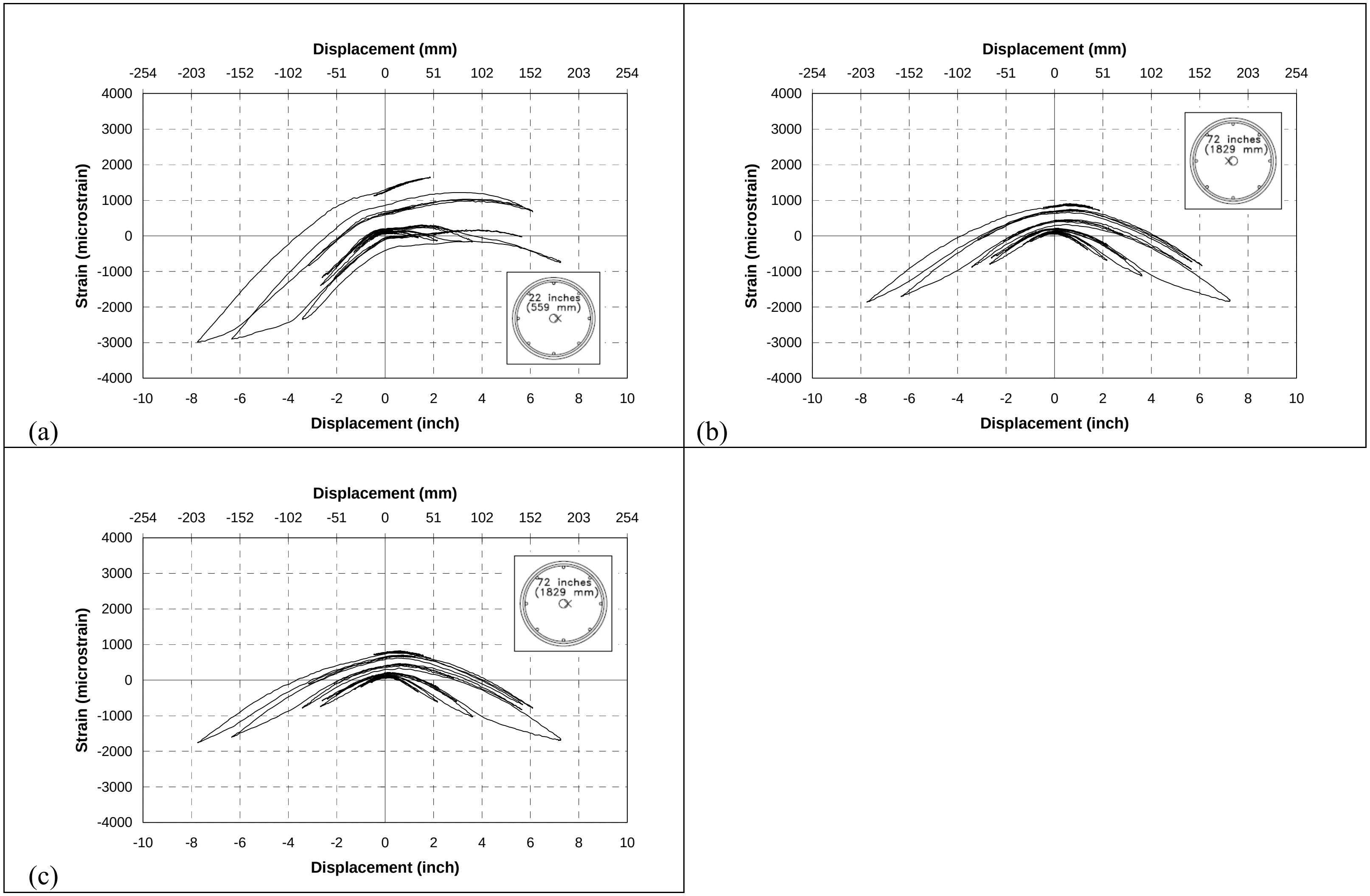

Fig. A-62. a) sg 60, b) sg 61, c) sg 62 in SE-2

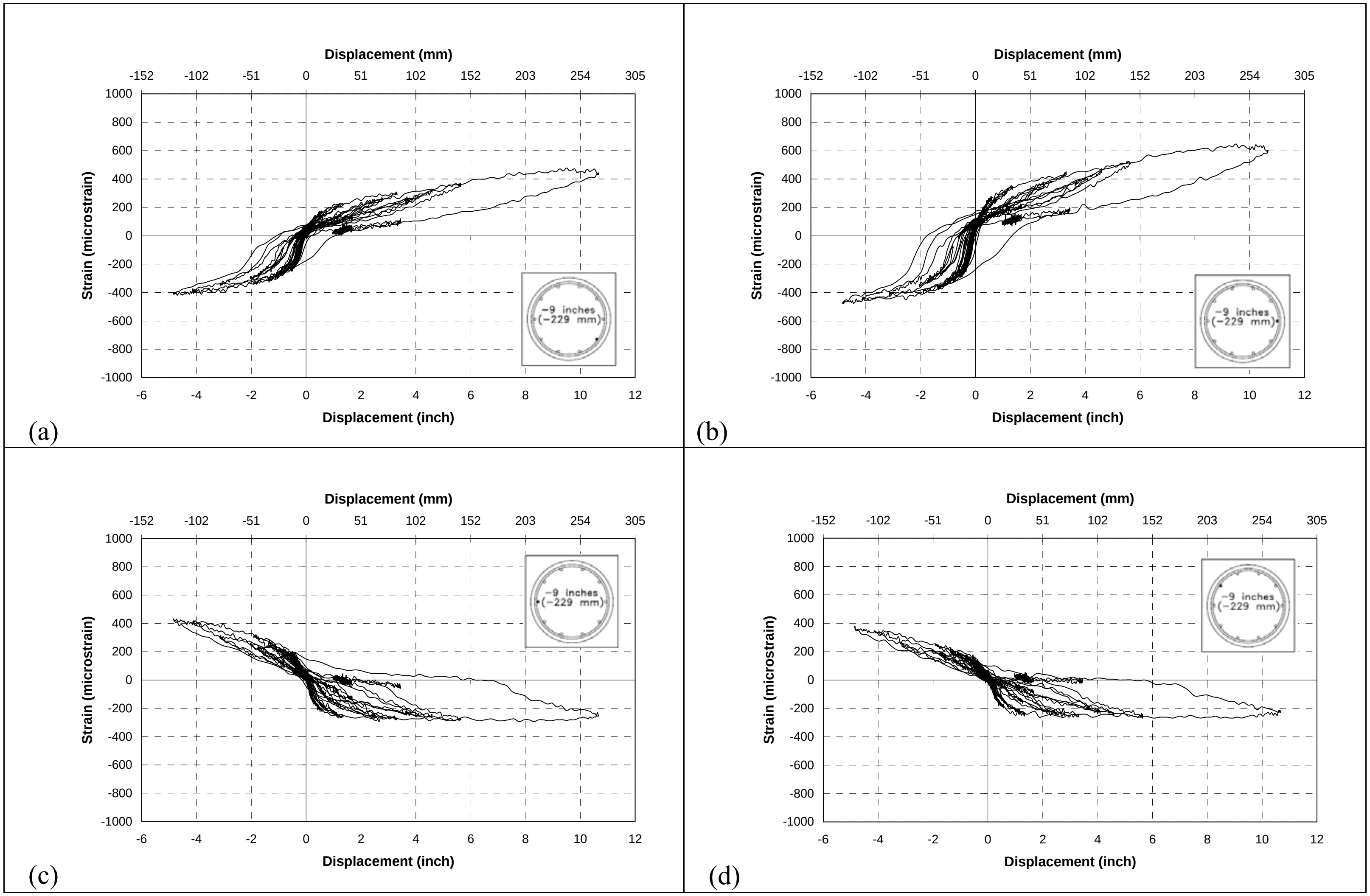

Fig. A-63. a) sg 1, b) sg 2, c) sg 3, d) sg 4 in SC-2R

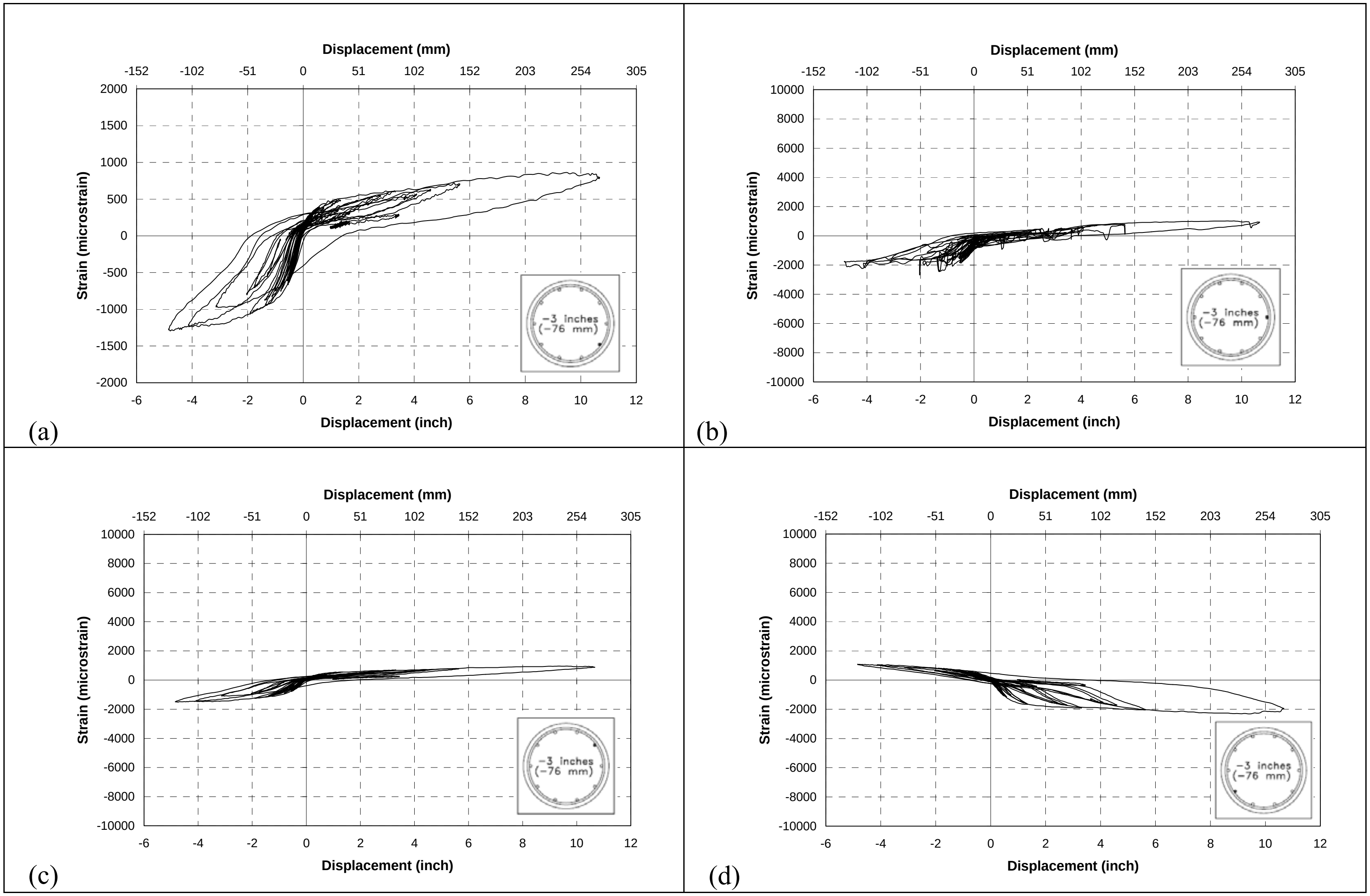

Fig. A-64. a) sg 5, b) sg 6, c) sg 7, d) sg 8 in SC-2R

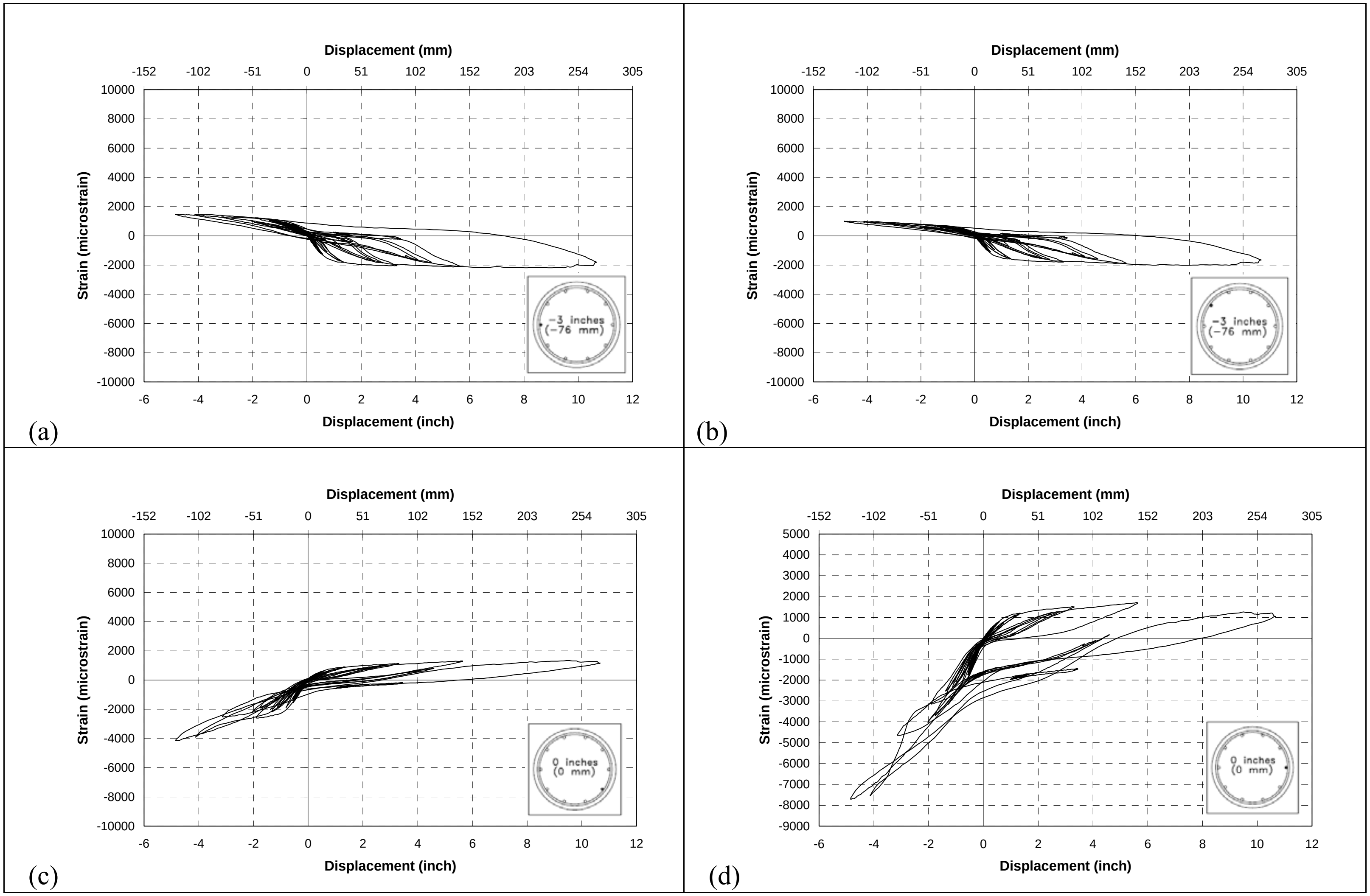

Fig. A-65. a) sg 9, b) sg 10, c) sg 11, d) sg 12 in SC-2R

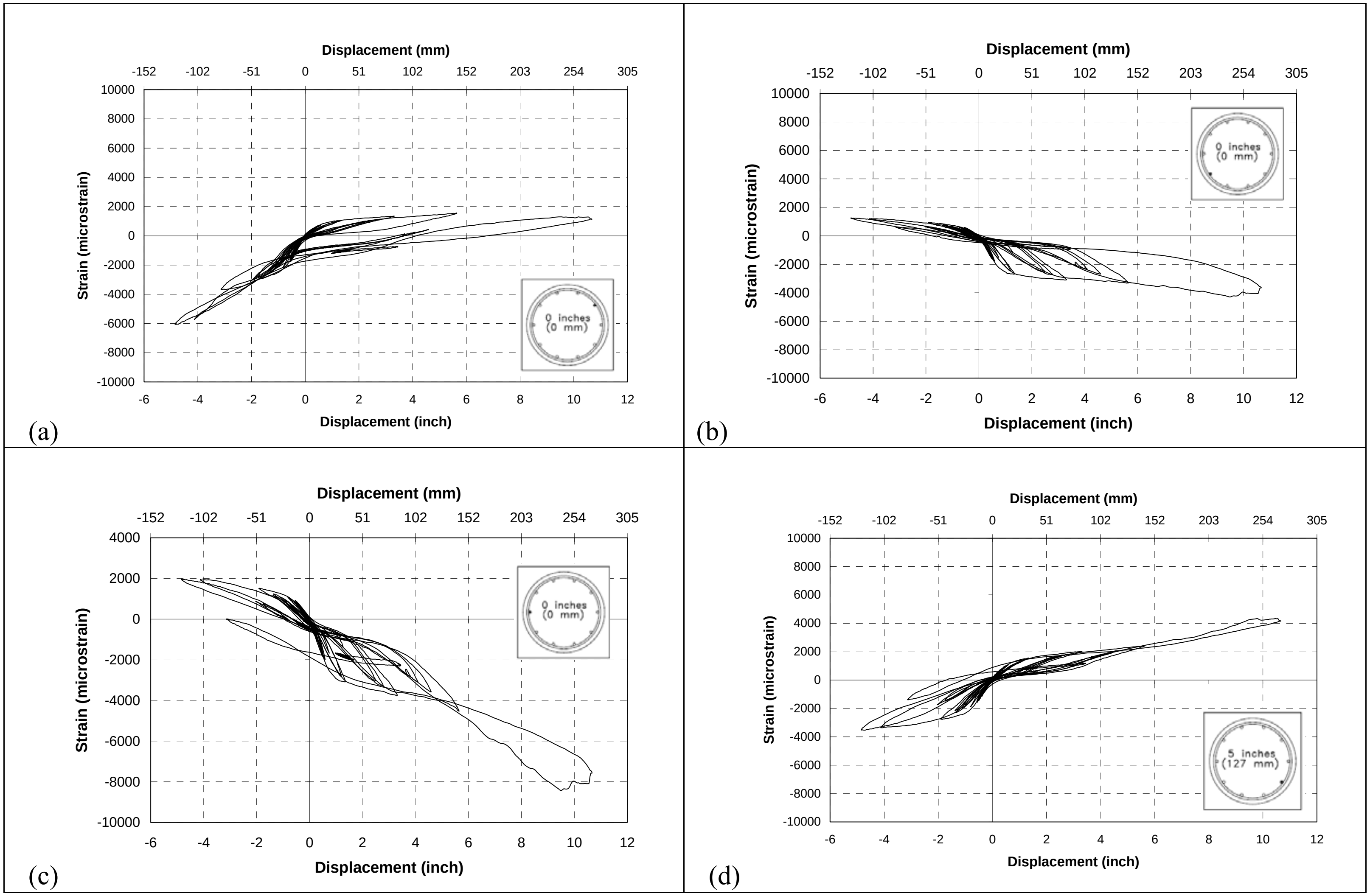

Fig. A-66. a) sg 13, b) sg 14, c) sg 15, d) sg 17 in SC-2R

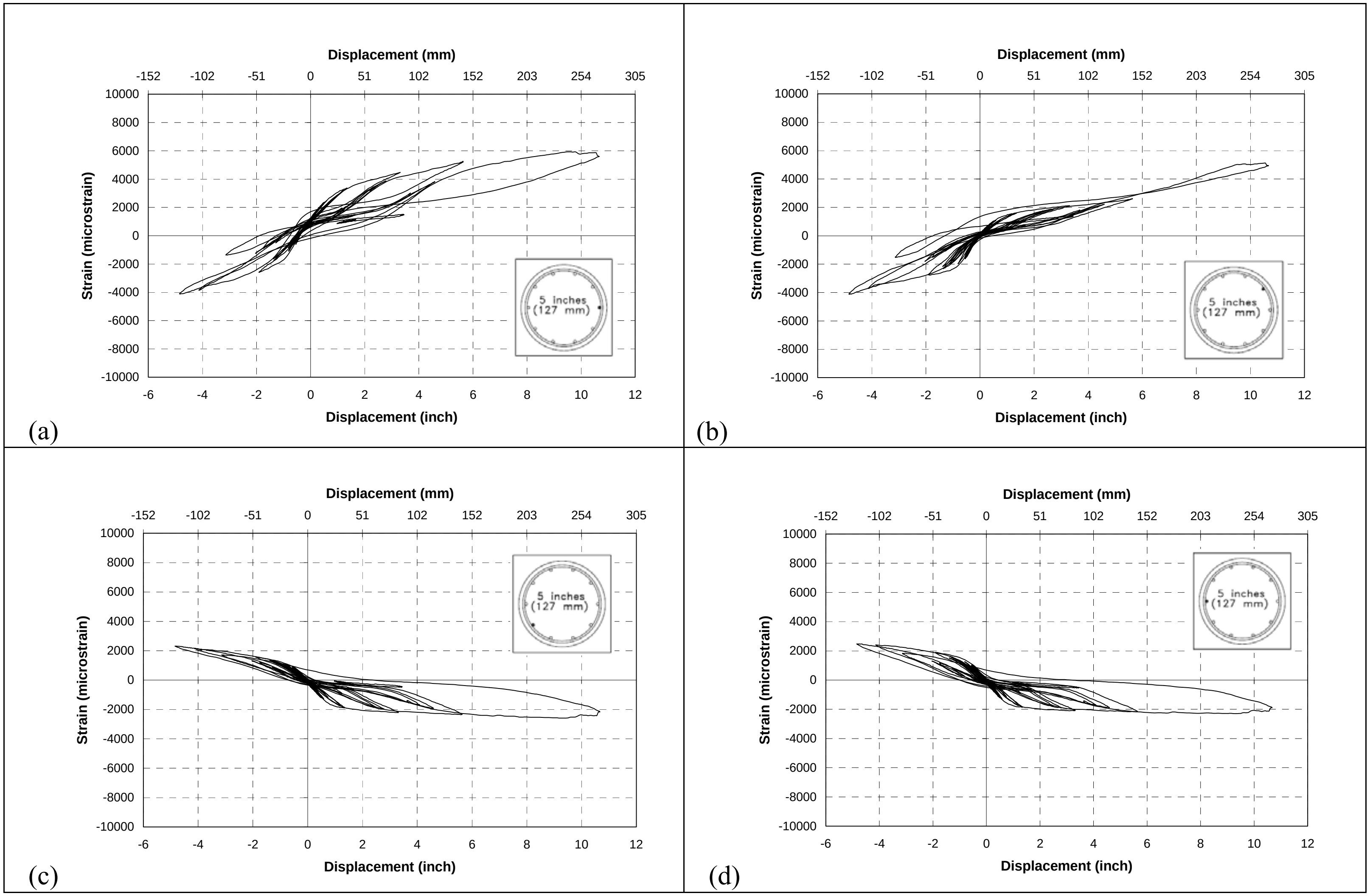

Fig. A-67. a) sg 18, b) sg 19, c) sg 20, d) sg 21 in SC-2R

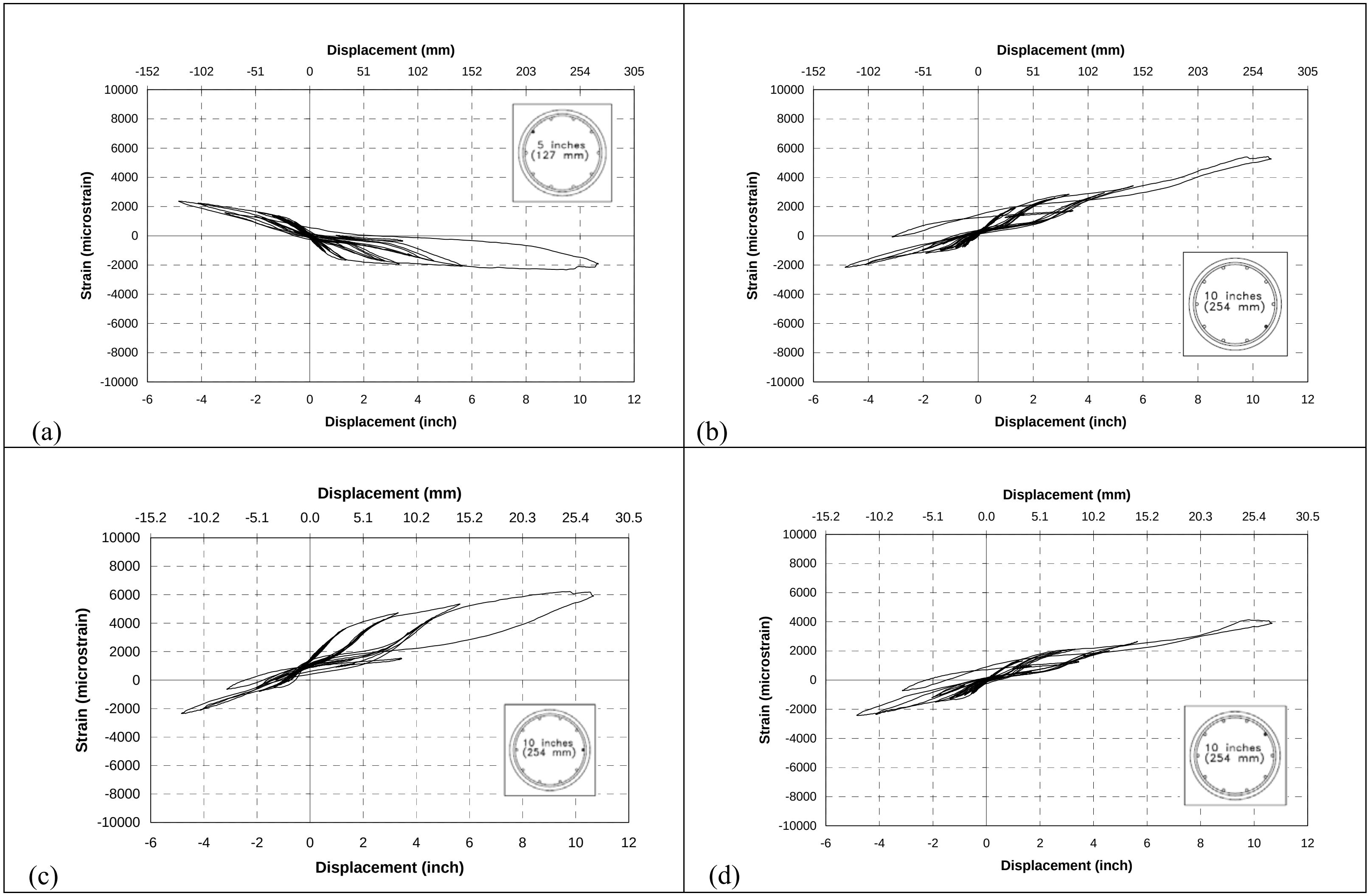

Fig. A-68. a) sg 22, b) sg 23, c) sg 24, d) sg 25 in SC-2R

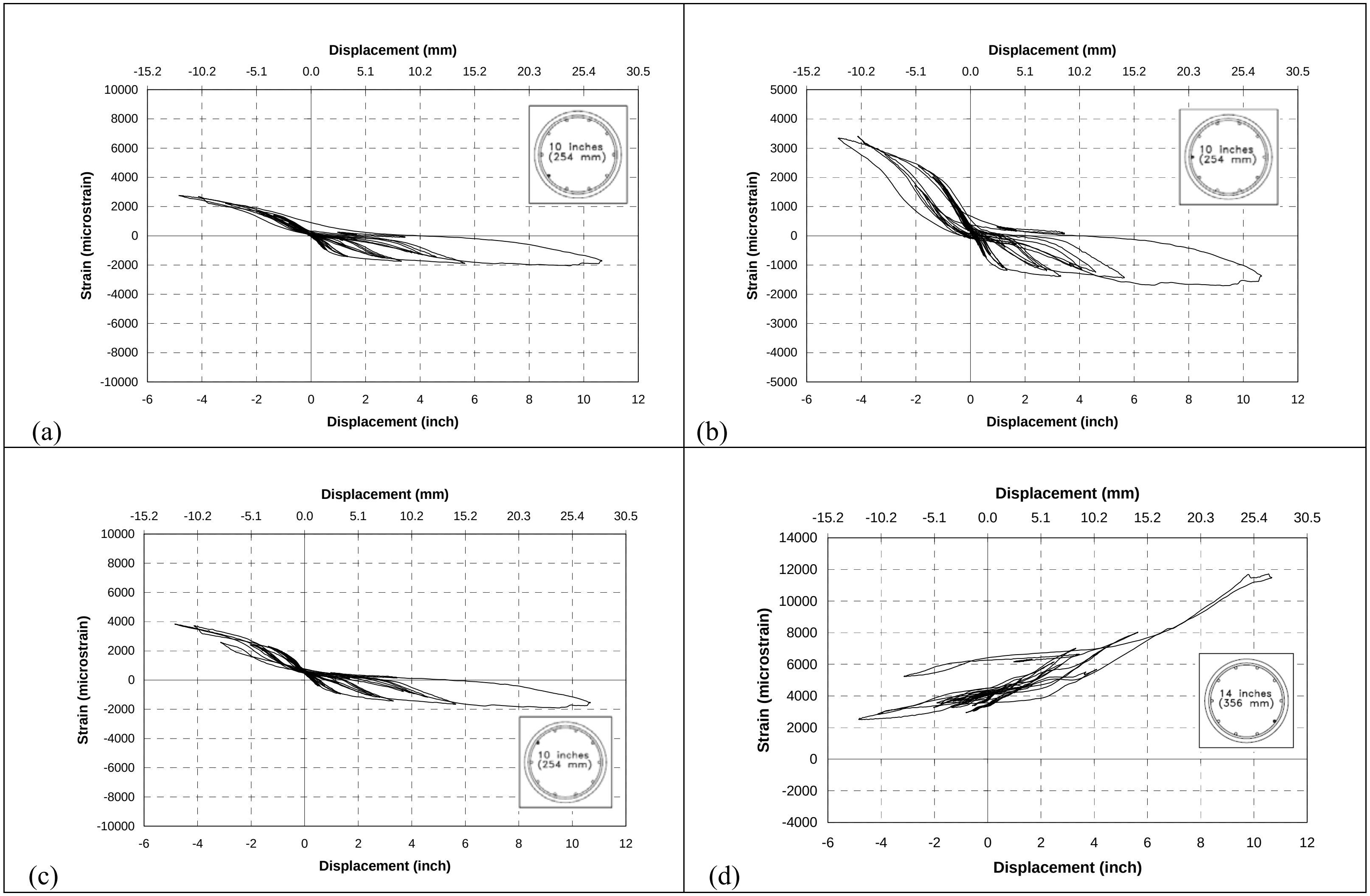

Fig. A-69. a) sg 26, b) sg 27, c) sg 28, d) sg 29 in SC-2R

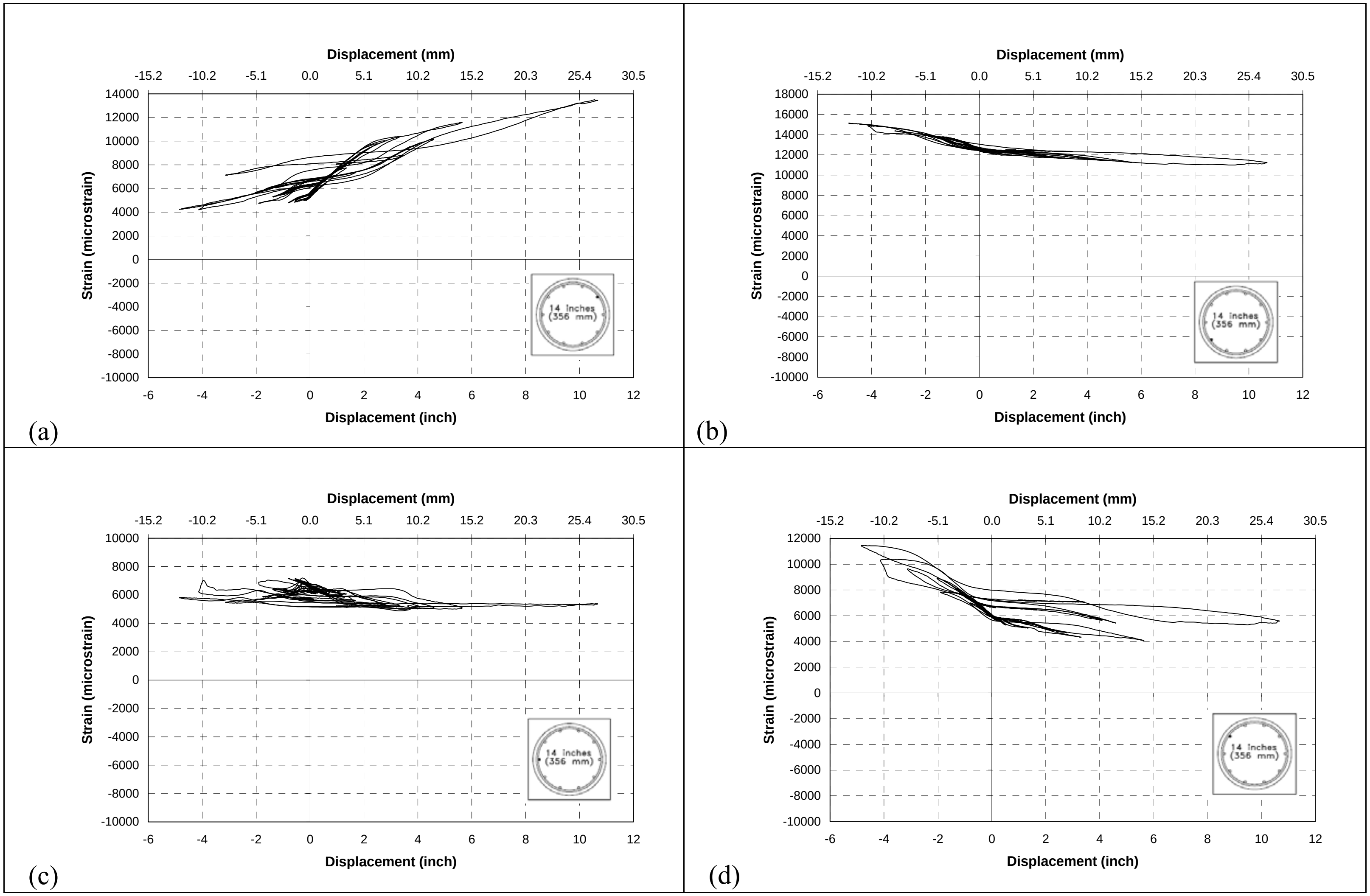

Fig. A-70. a) sg 31, b) sg 32, c) sg 33, d) sg 34 in SC-2R

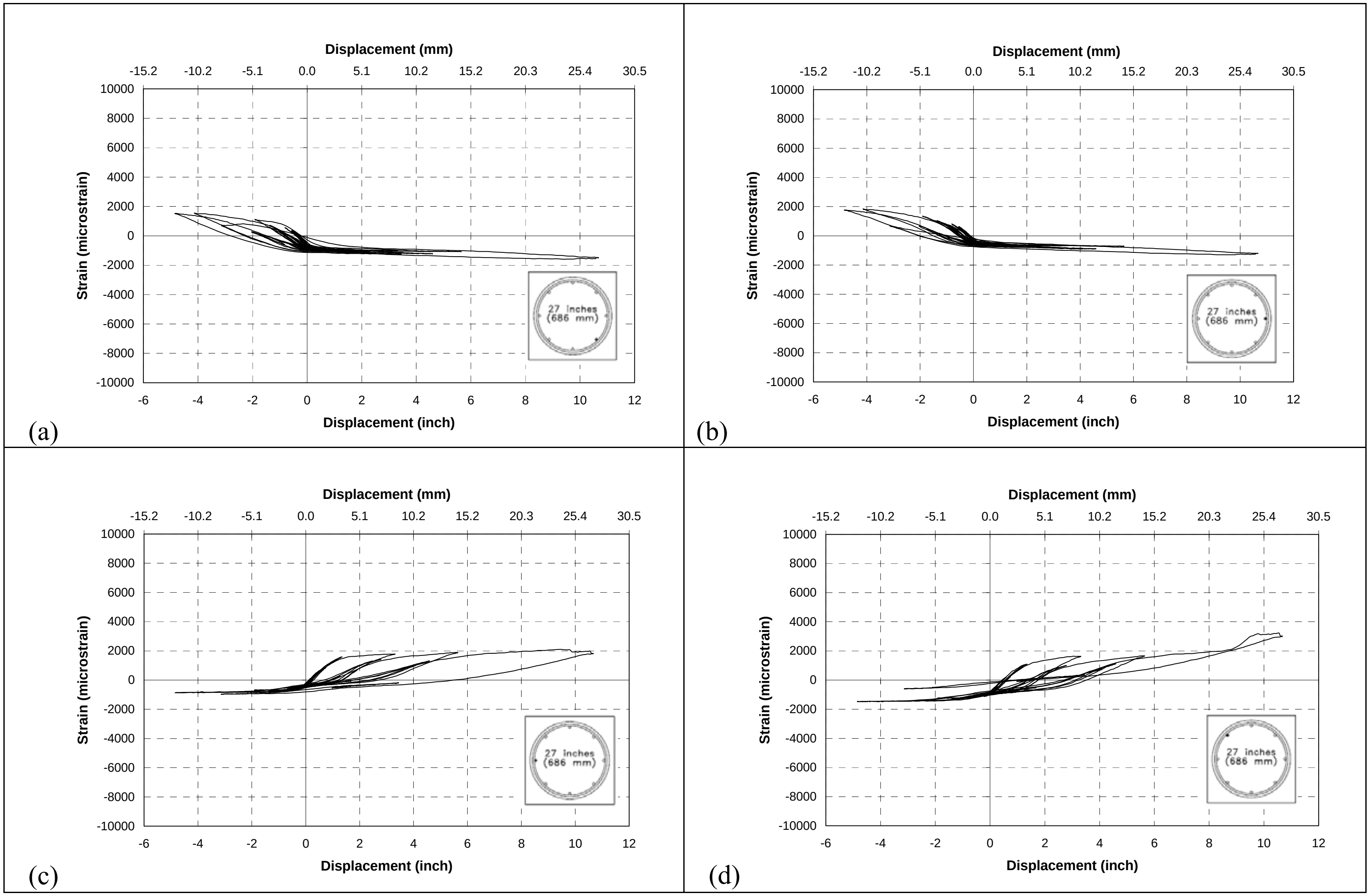

Fig. A-71. a) sg 35, b) sg 36, c) sg 37, d) sg 38 in SC-2R

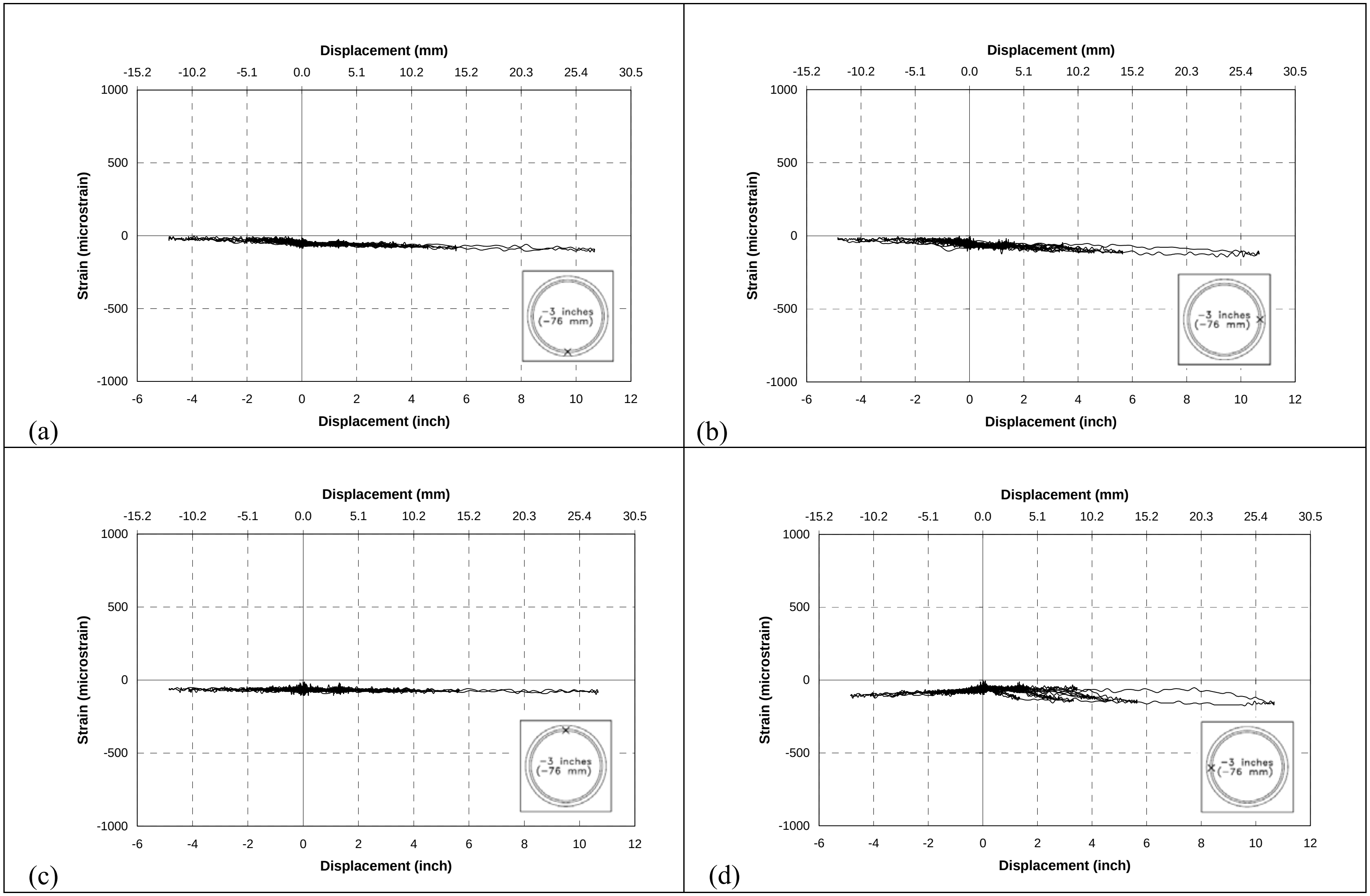

Fig. A-72. a) sg 39, b) sg 40, c) sg 41, d) sg 42 in SC-2R

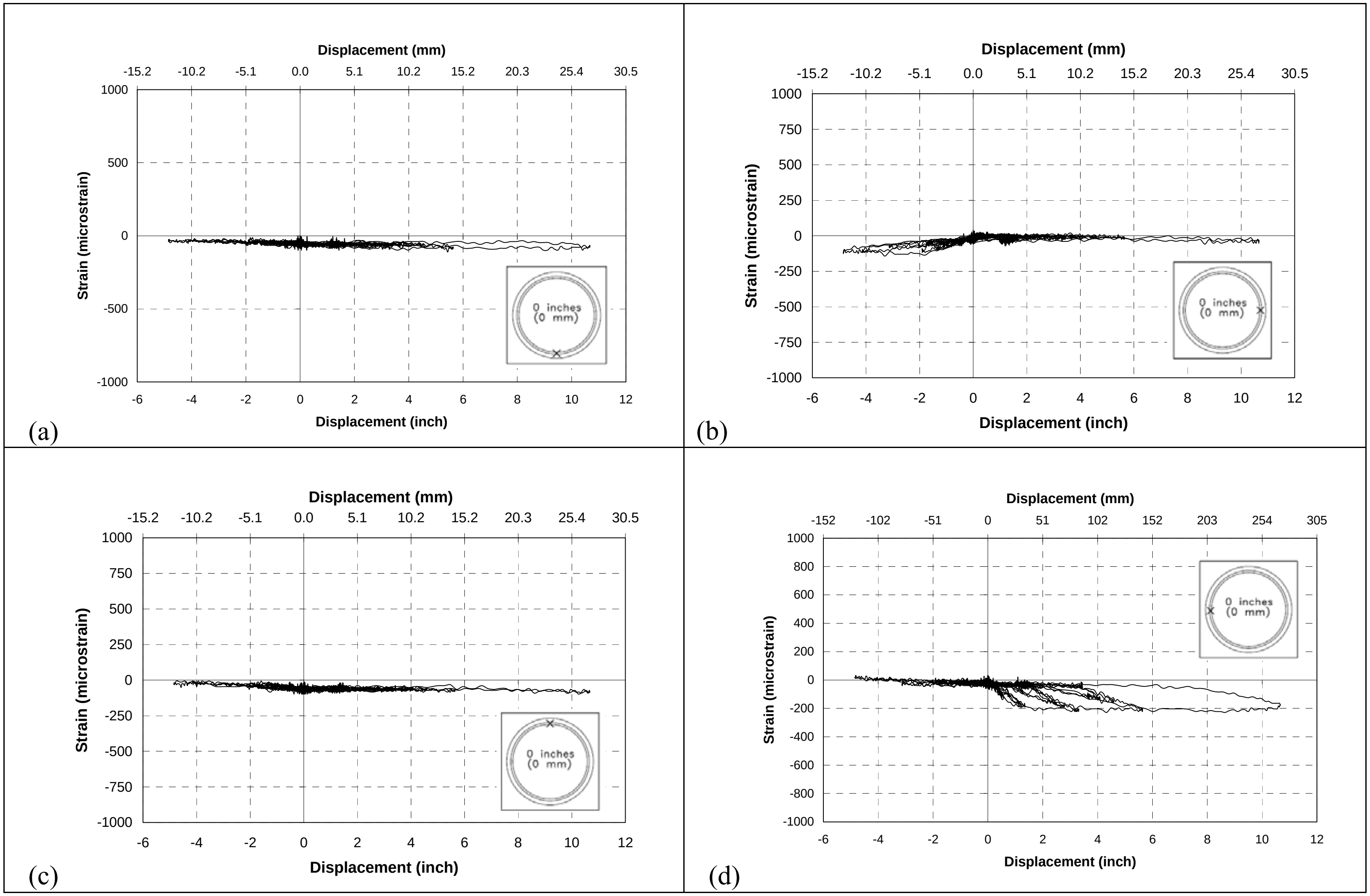

Fig. A-73 a) sg 43, b) sg 44, c) sg 45, d) sg 46 in SC-2R

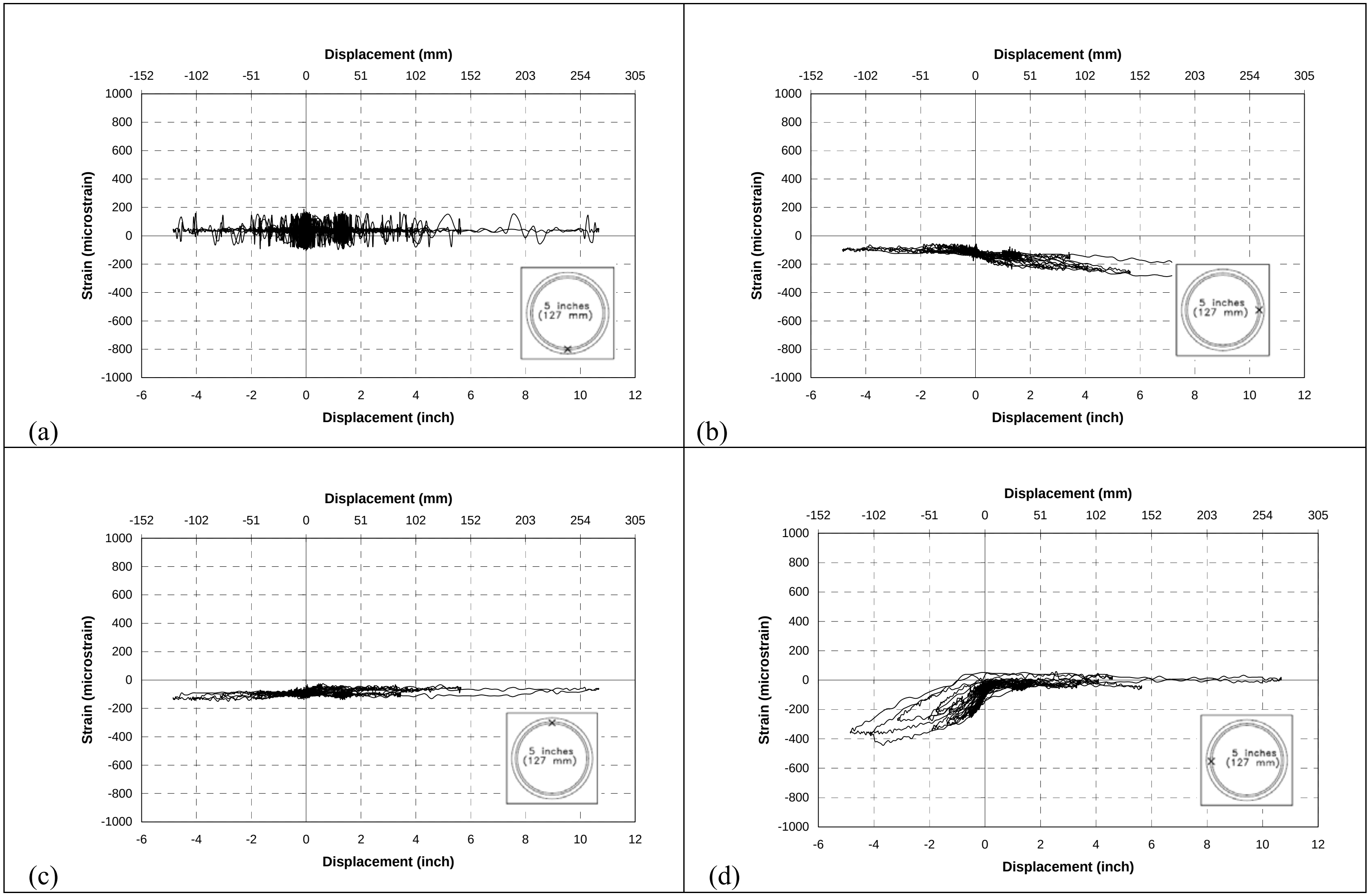

Fig. A-74. a) sg 47, b) sg 48, c) sg 49, d) sg 50 in SC-2R

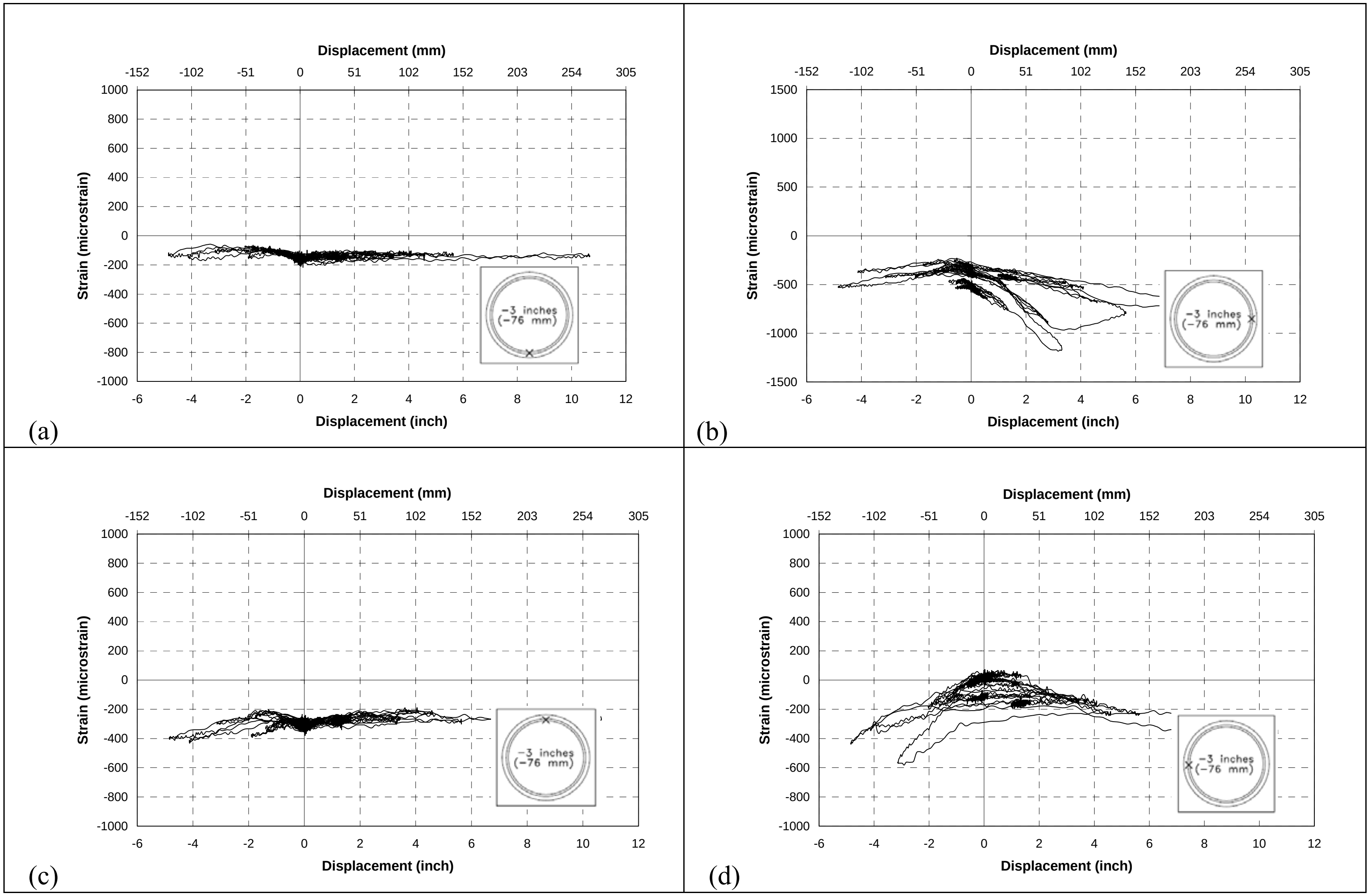

Fig. A-75. a) sg 51, b) sg 52, c) sg 53, d) sg 54 in SC-2R

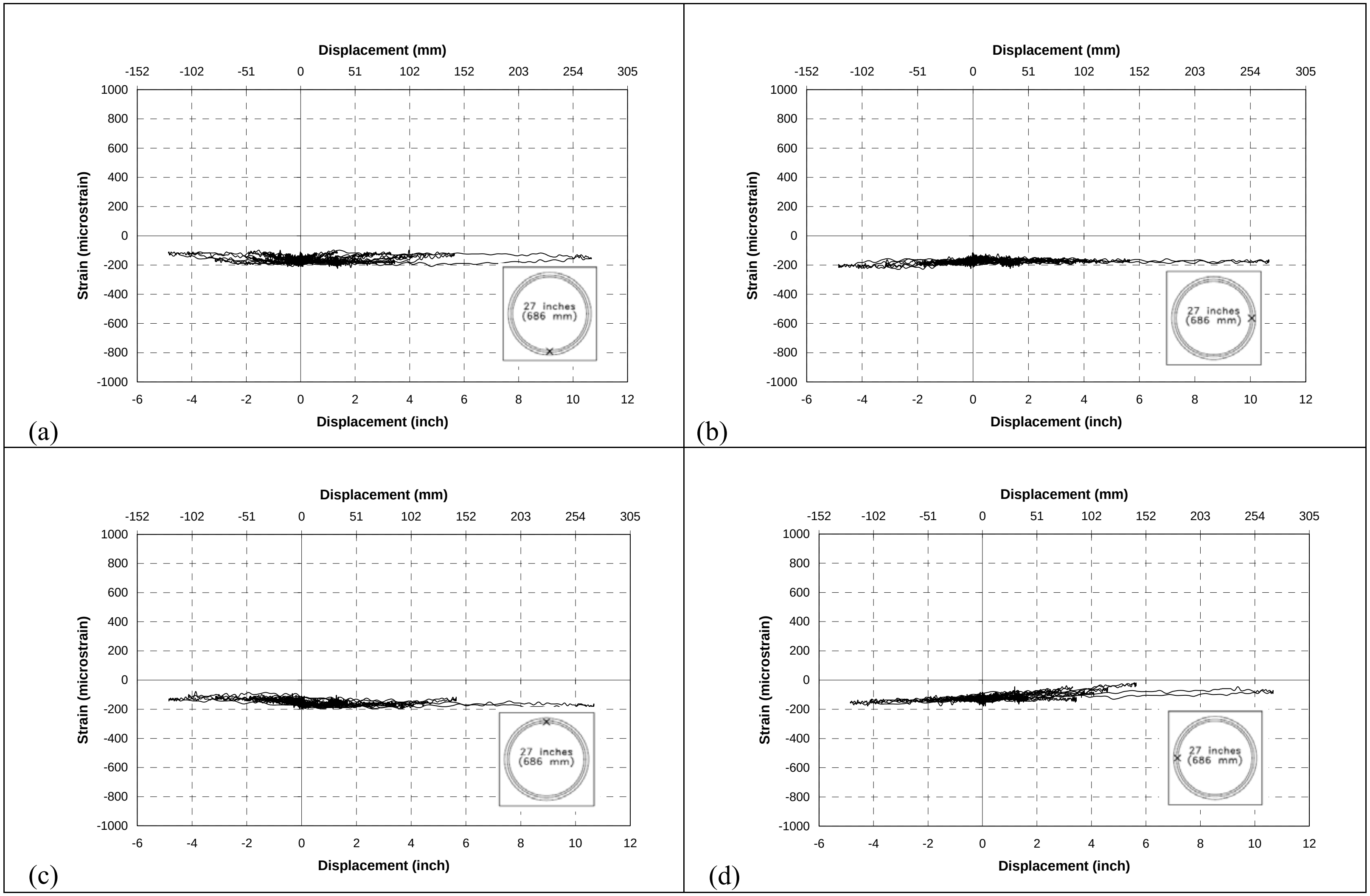

Fig. A-76. a) sg 55, b) sg 56, c) sg 57, d) sg 58 in SC-2R

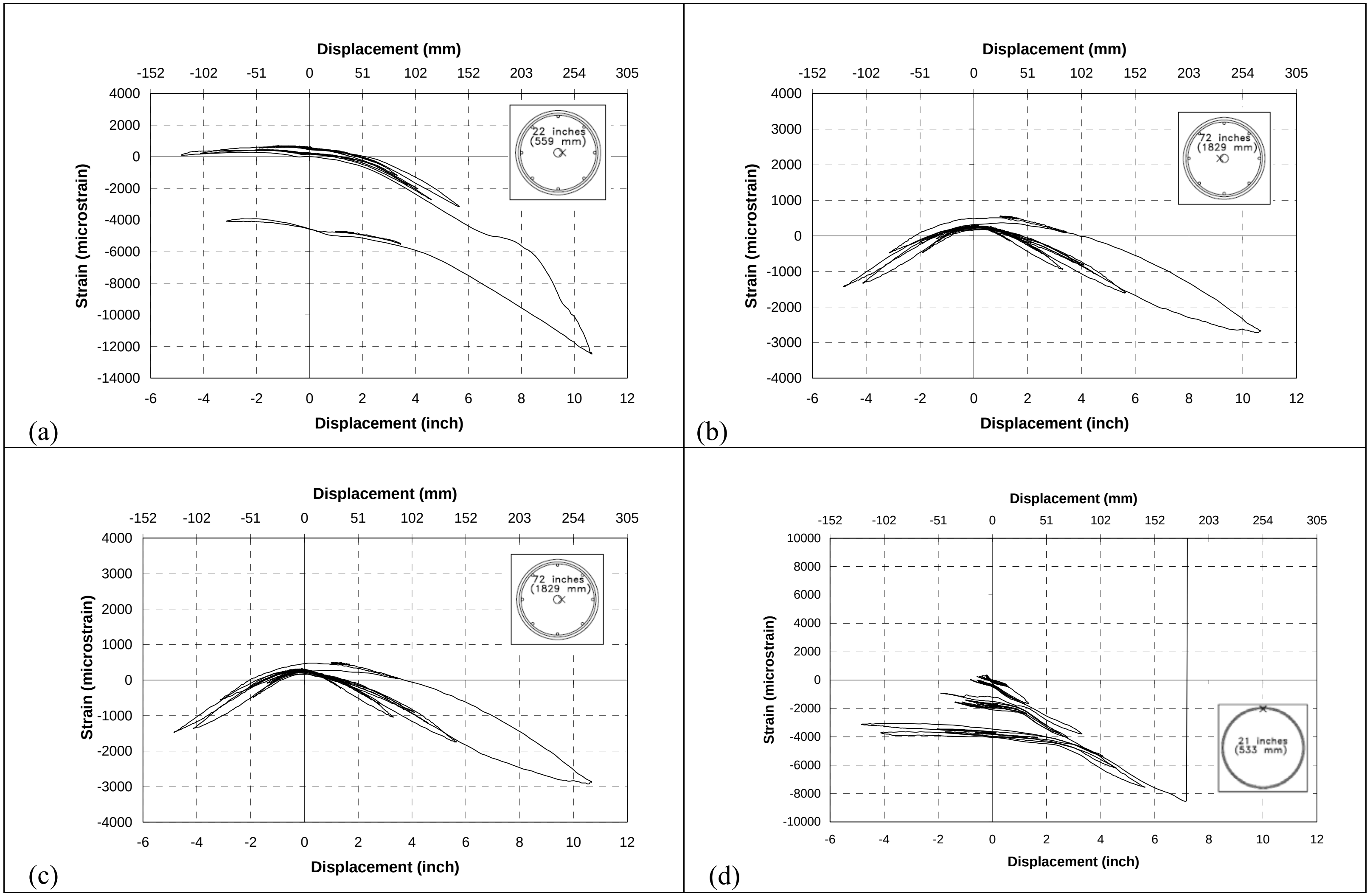

Fig. A-77. a) sg 60 (on the PT Rod), b) sg 61(on the PT Rod), c) sg 62(on the PT Rod), d) sg 63 (on the FRP Wrap) in SC-2R

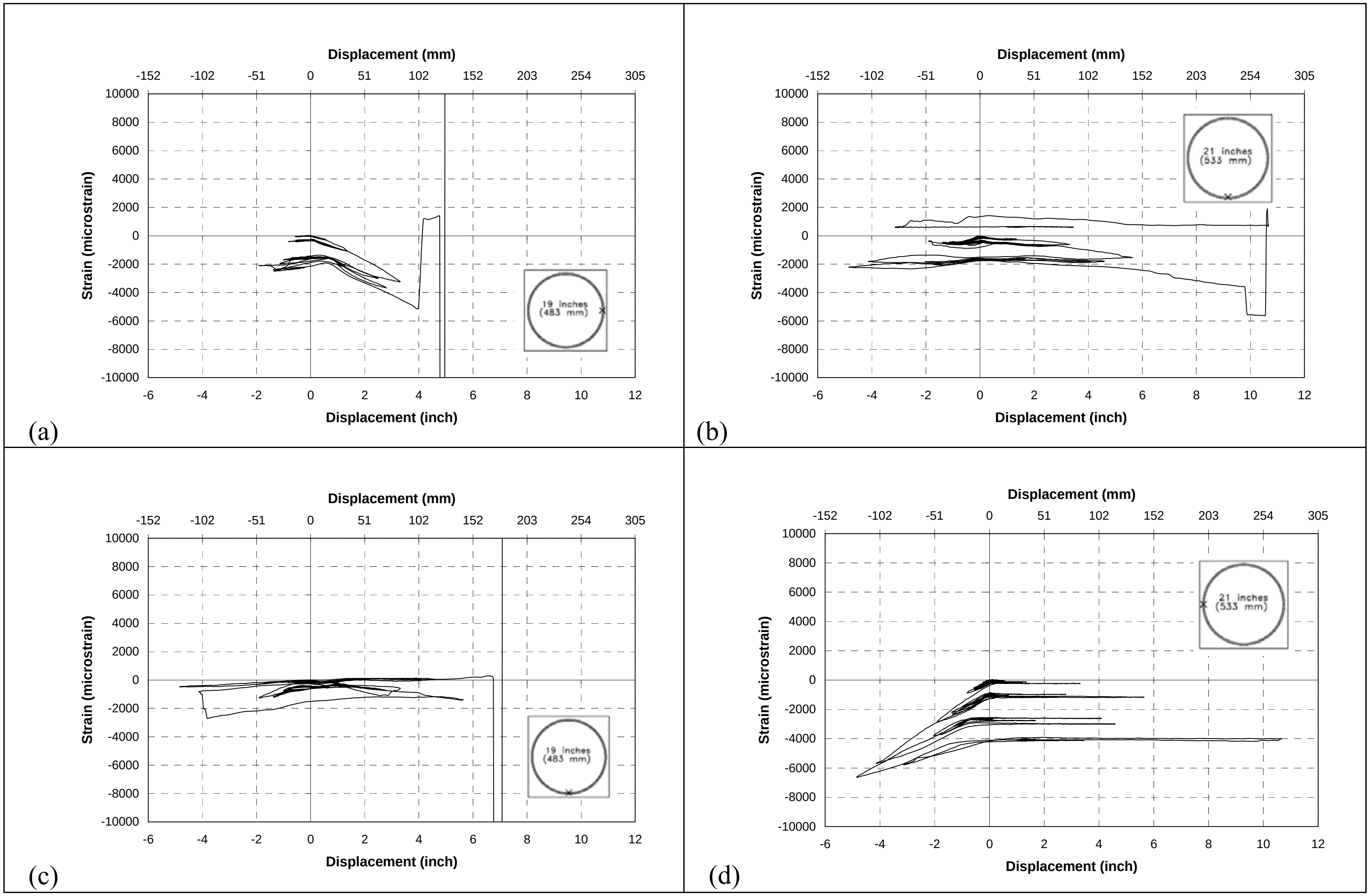

Fig. A-78. a) sg 64, b) sg 65, c) sg 66, d) sg 67 in SC-2R (on the FRP Wrap)

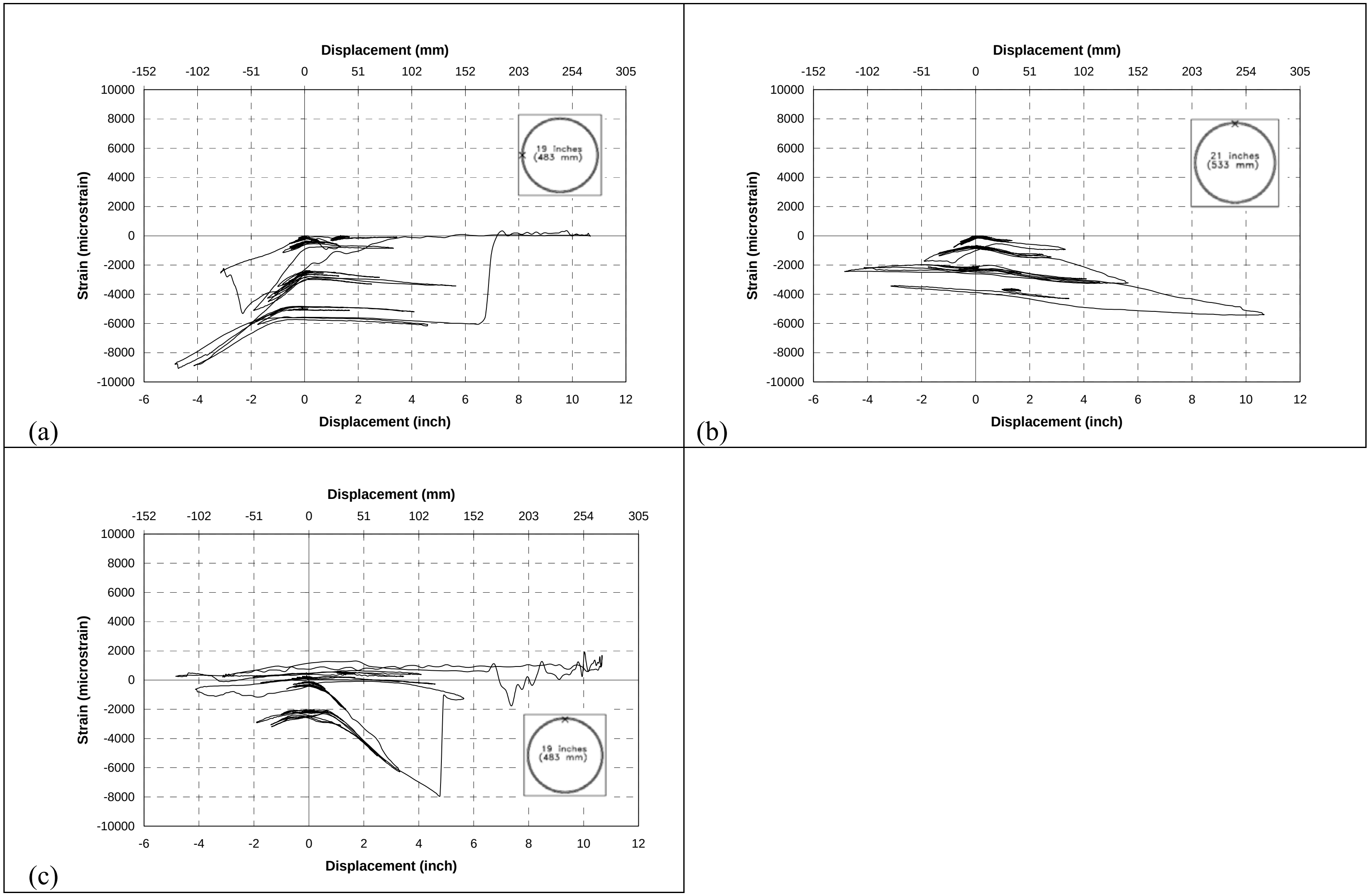

Fig. A-79. a) sg 68, b) sg 69, c) sg 70, in SC-2R (on the FRP Wrap)

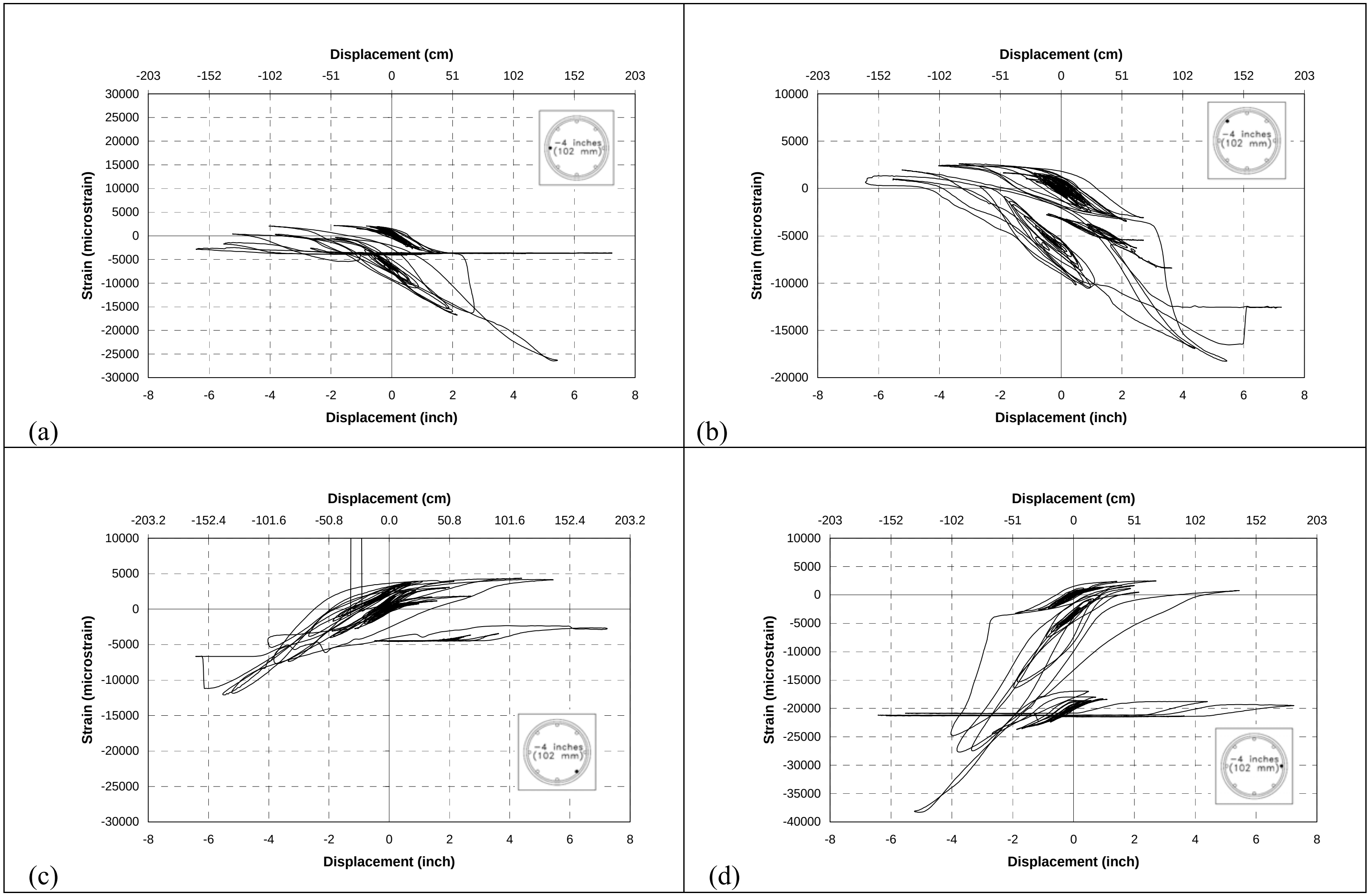

Fig. A-80. a) sg 1, b) sg 2, c) sg 3, d) sg 4 for RC-ECC Column in PEFB

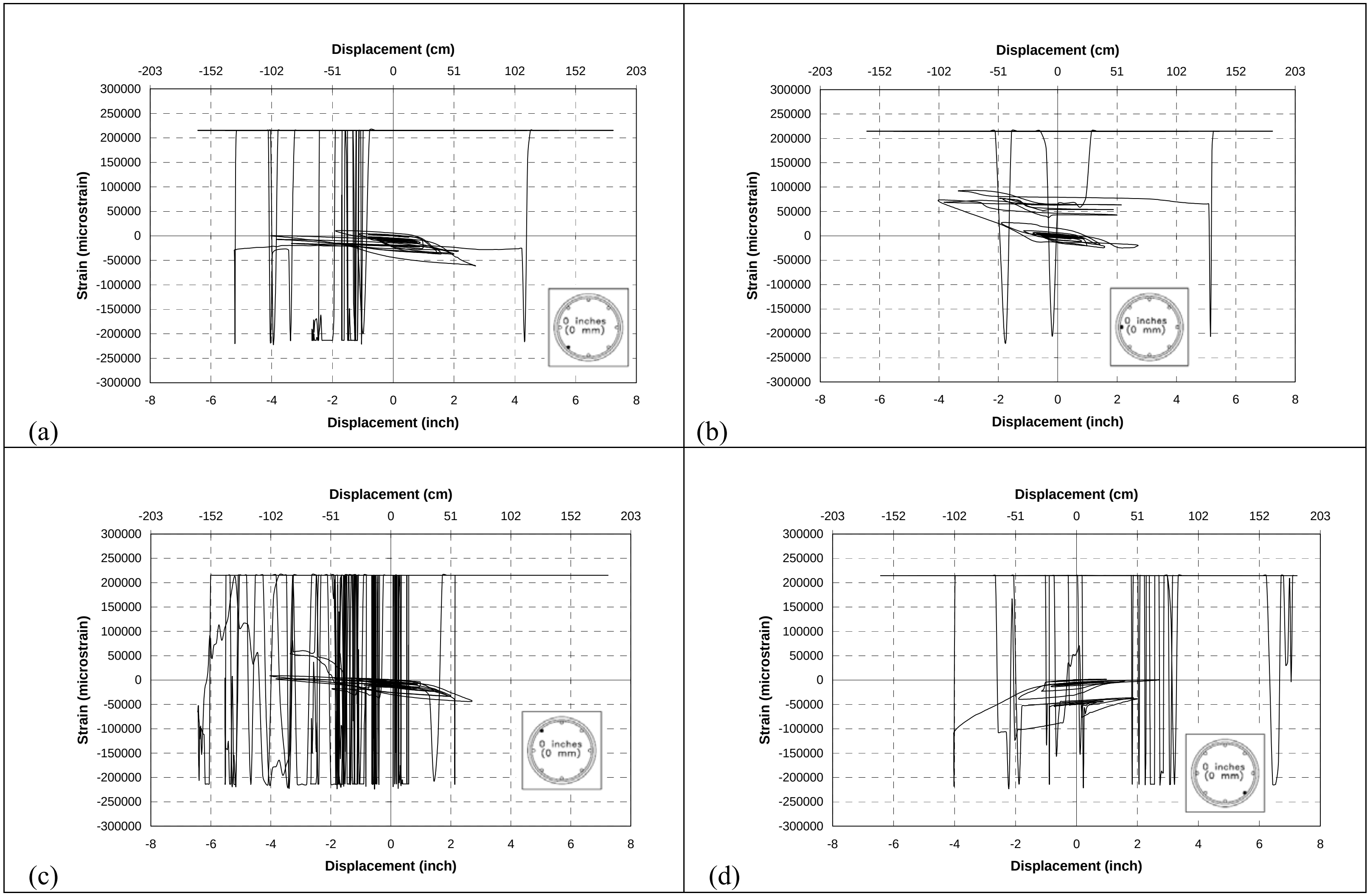

Fig. A-81. a) sg 5, b) sg 6, c) sg 7, d) sg 8 for RC-ECC Column in PEFB

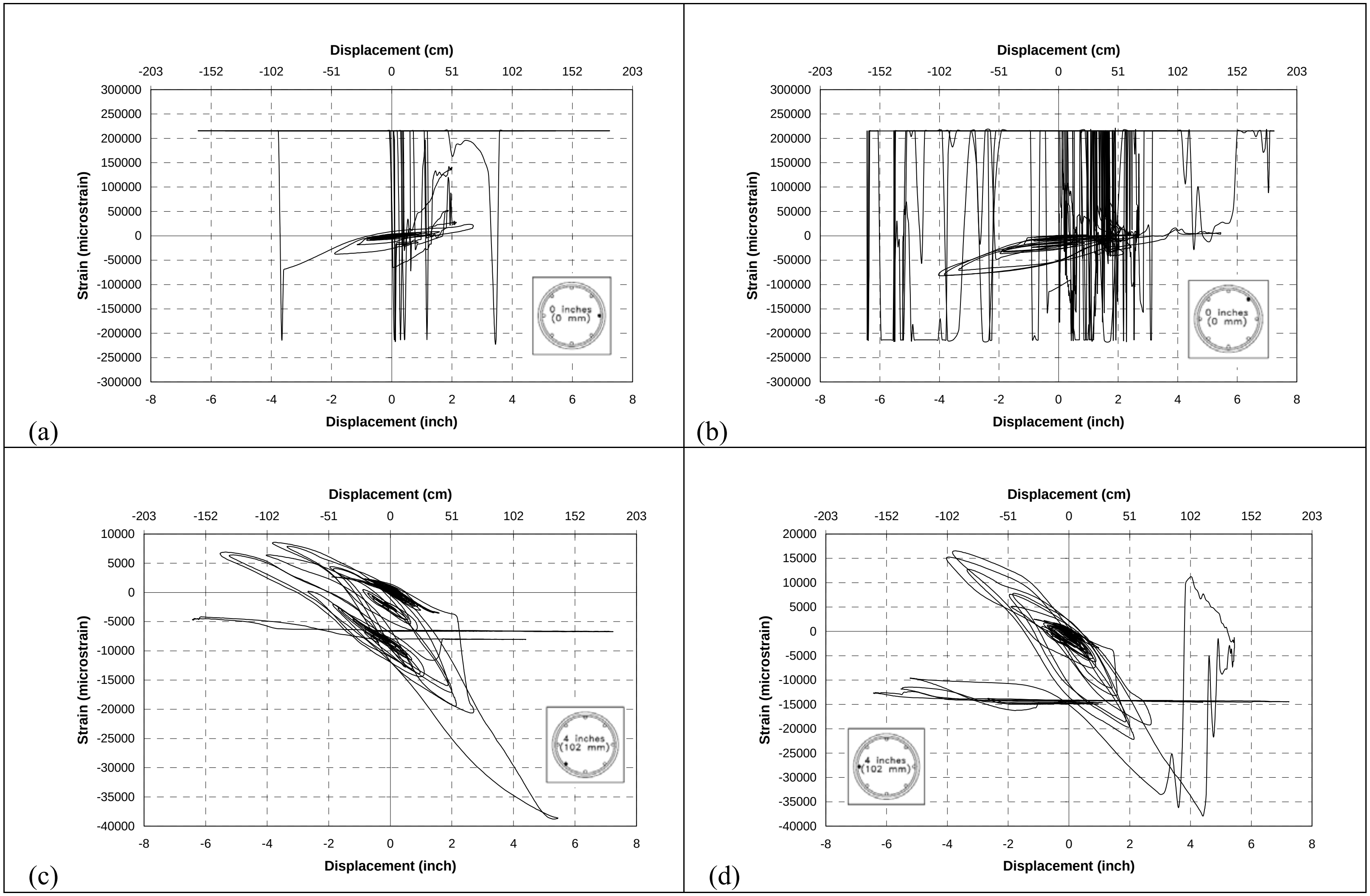

Fig. A-82. a) sg 9, b) sg 10, c) sg 11, d) sg 12 for RC-ECC Column in PEFB

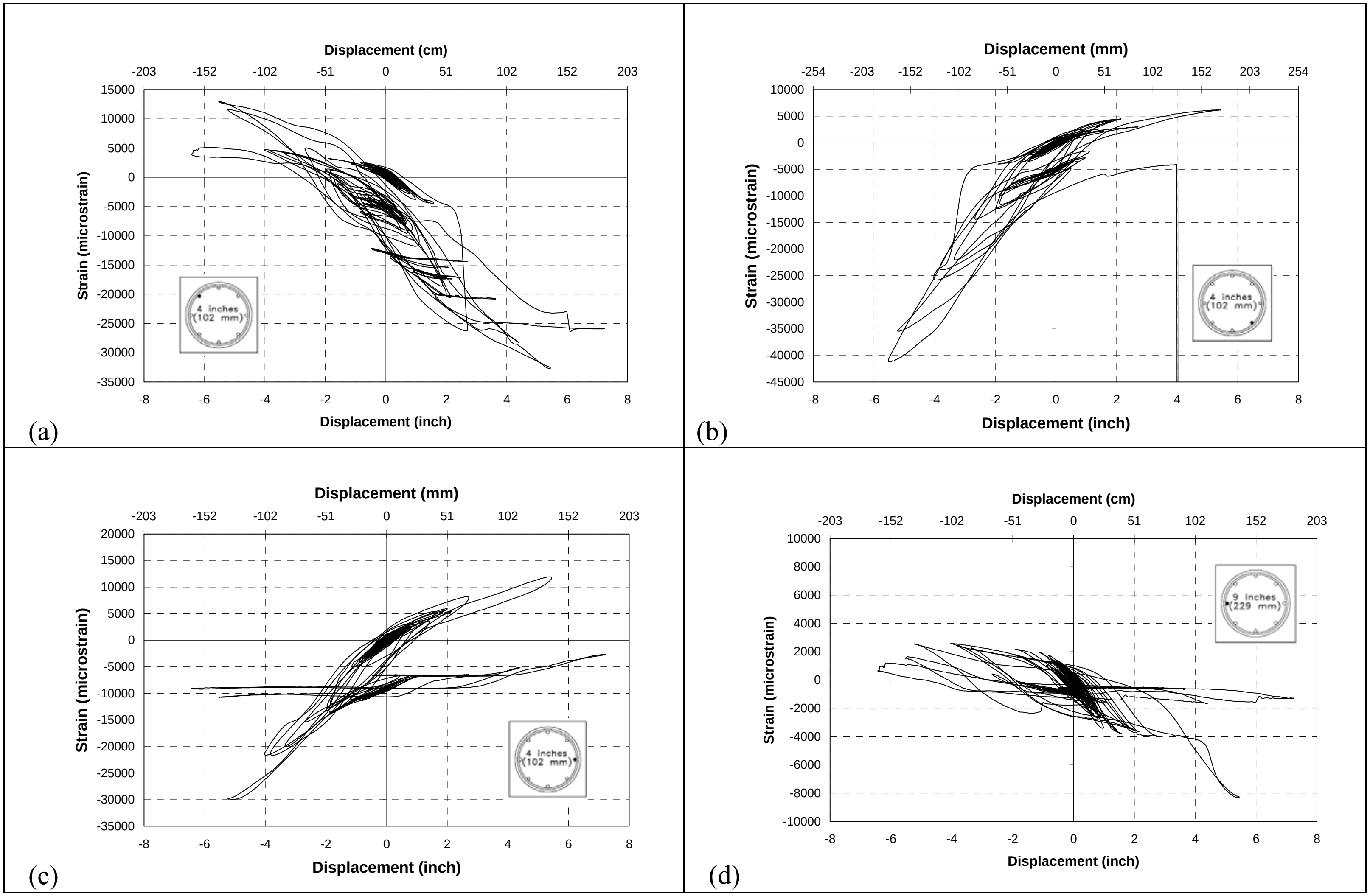

Fig. A-83. a) sg 13, b) sg 14, c) sg 15, d) sg 17 for RC-ECC Column in PEFB

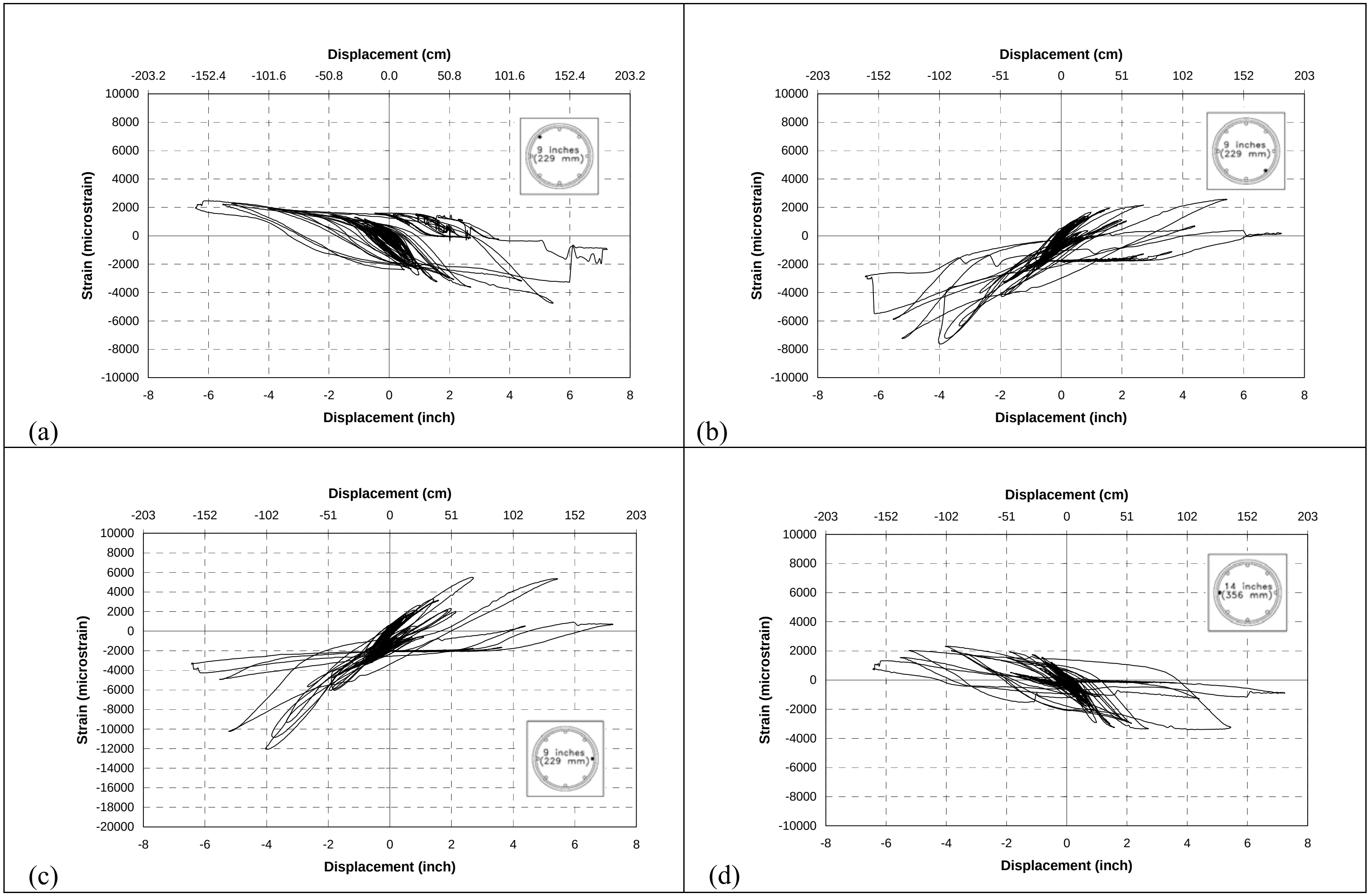

Fig. A-84. a) sg 18, b) sg 19, c) sg 20, d) sg 21 for RC-ECC Column in PEFB

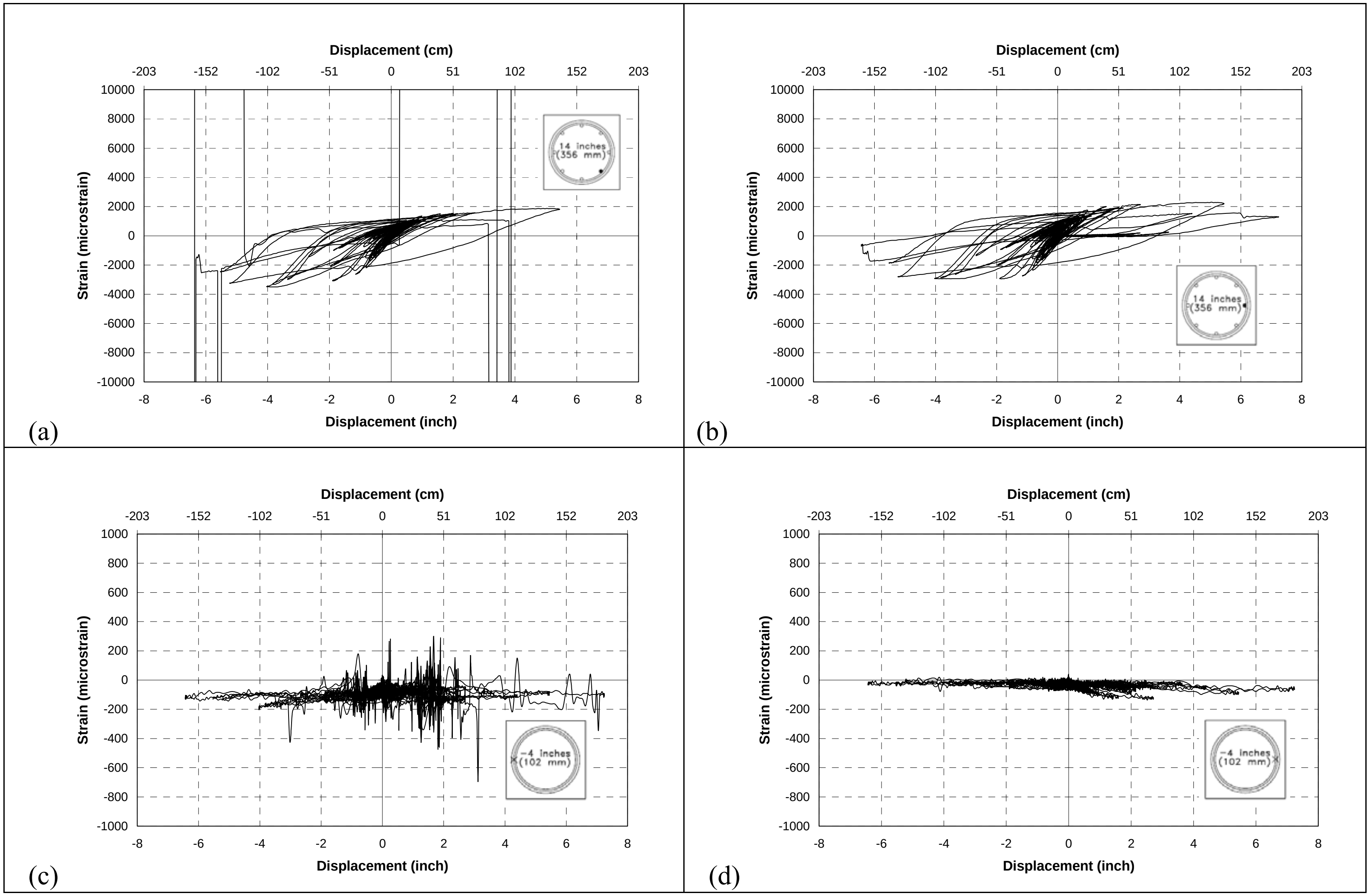

Fig. A-85. a) sg 23, b) sg 24, c) sg 25, d) sg 26 for RC-ECC Column in PEFB

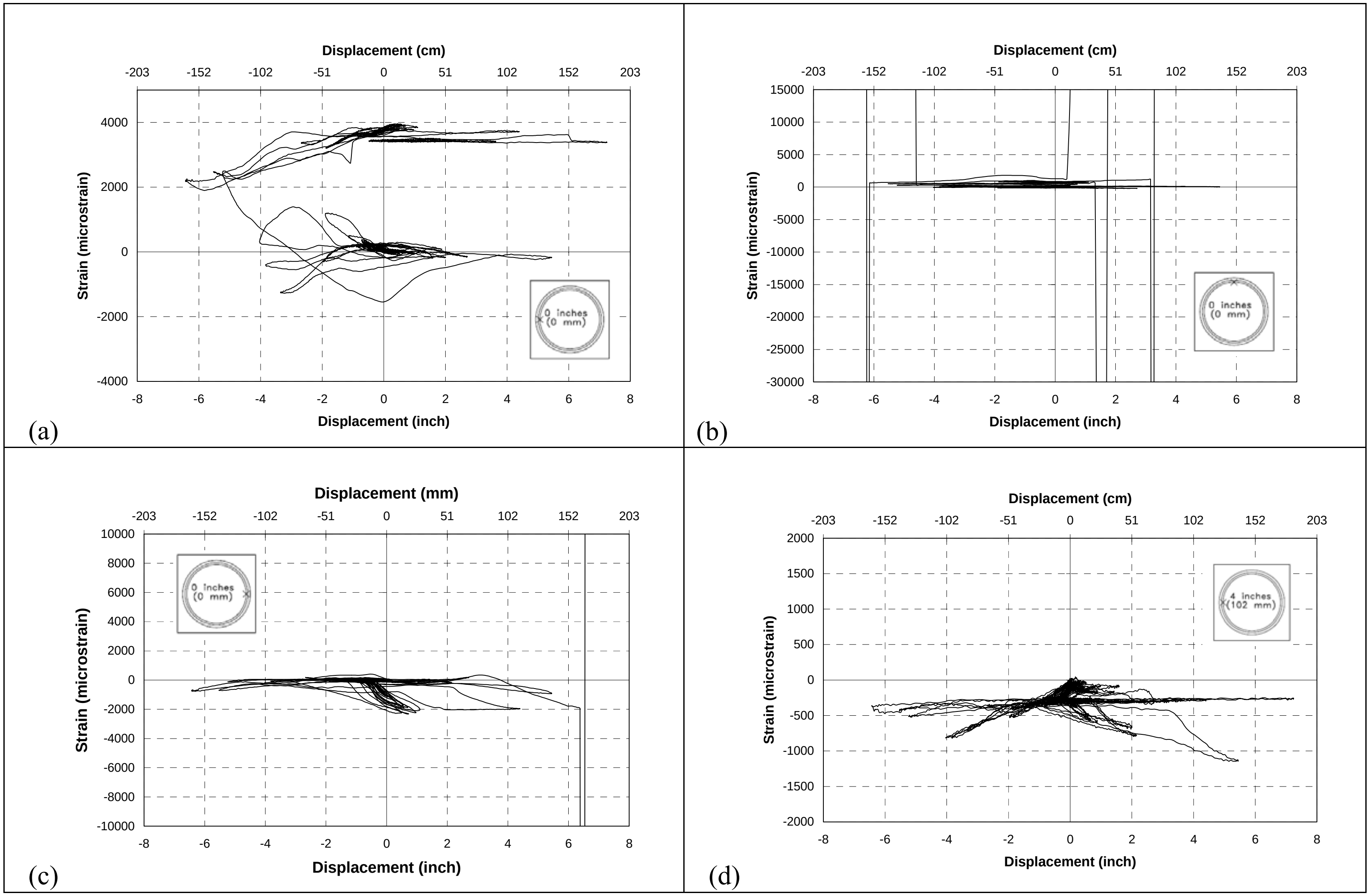

Fig. A-86. a) sg 27, b) sg 28, c) sg 29, d) sg 31 for RC-ECC Column in PEFB

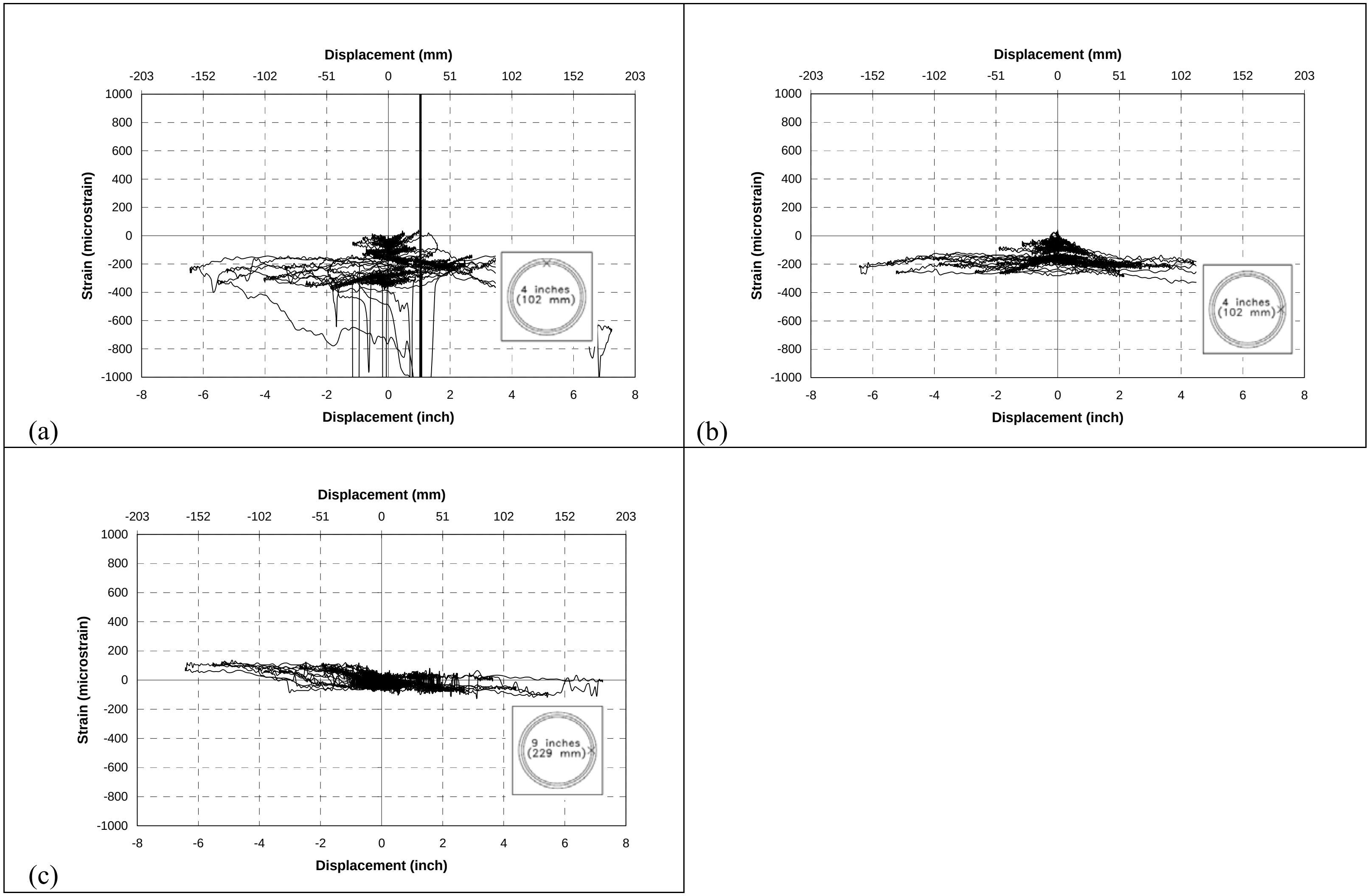

Fig. A-87. a) sg 32, b) sg 33, c) sg 36 for RC-ECC Column in PEFB

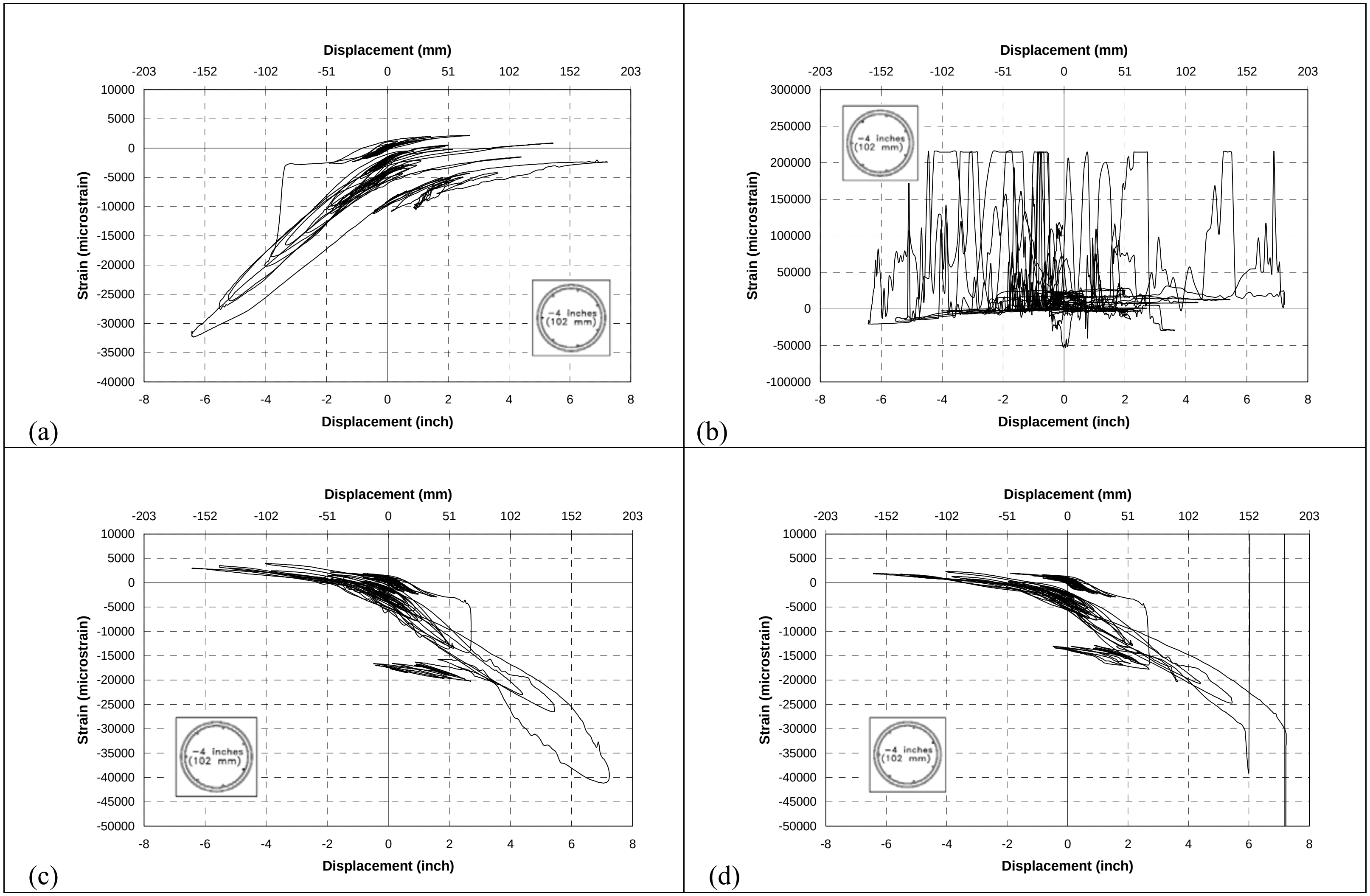

Fig. A-88. a) sg 37, b) 38, c) sg 39, d) sg 40 for FRP Column in PEFB

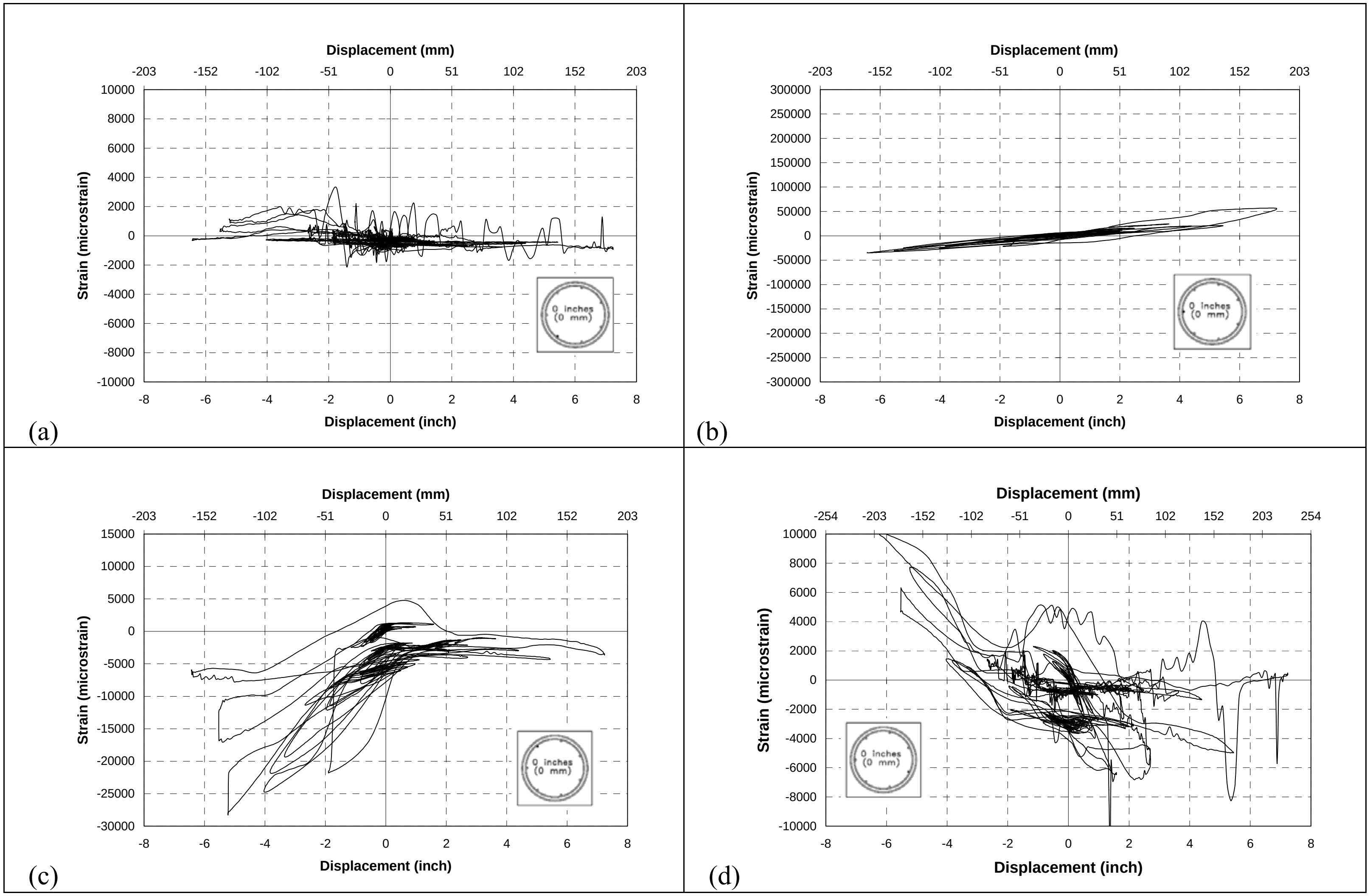

Fig. A-89. a) sg 41, b) sg 42, c) sg 43, d) sg 44 for FRP Column in PEFB

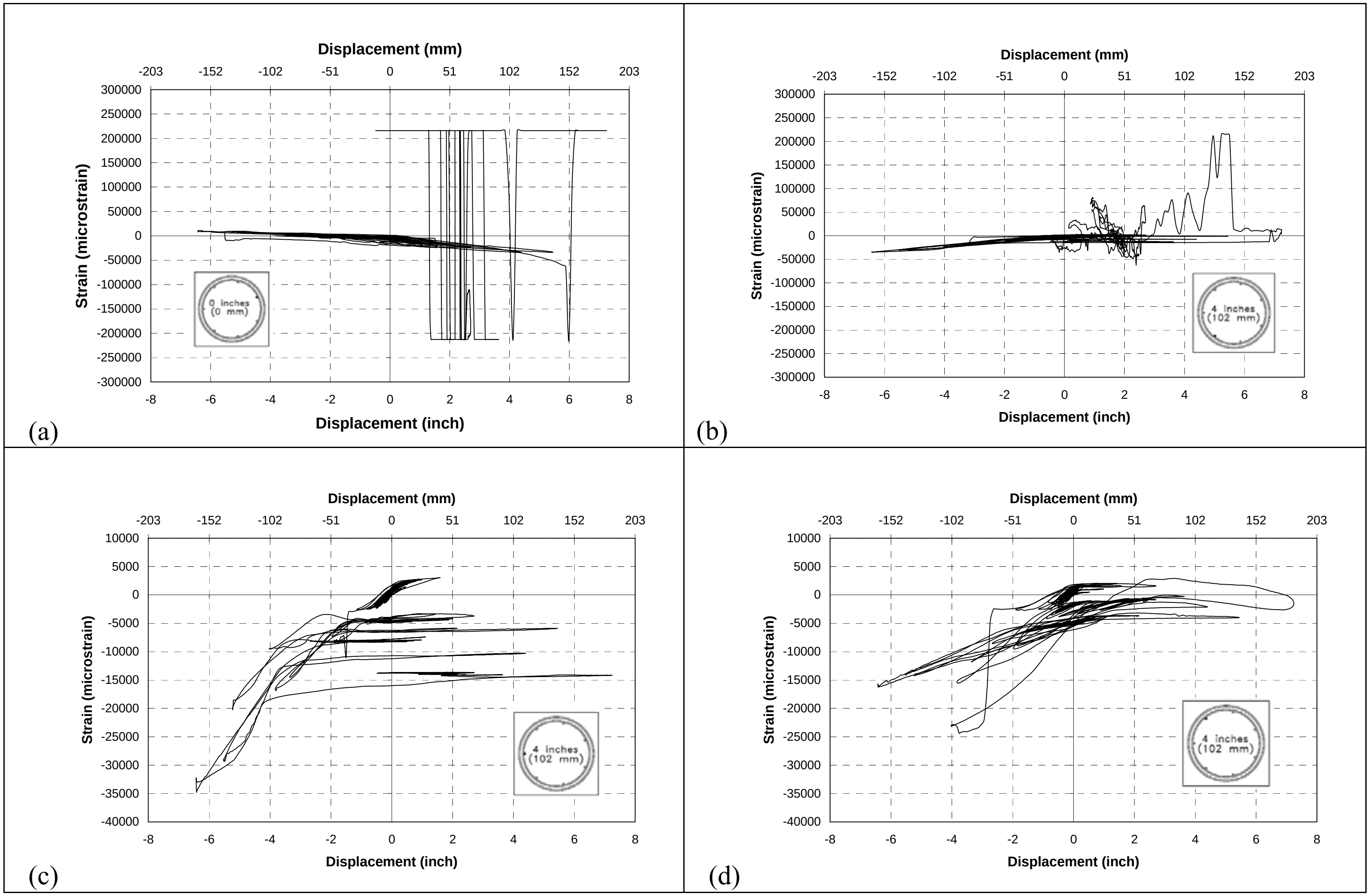

Fig. A-90. a) sg 45, b) sg 46, c) sg 47, d) sg 48 for FRP Column in PEFB

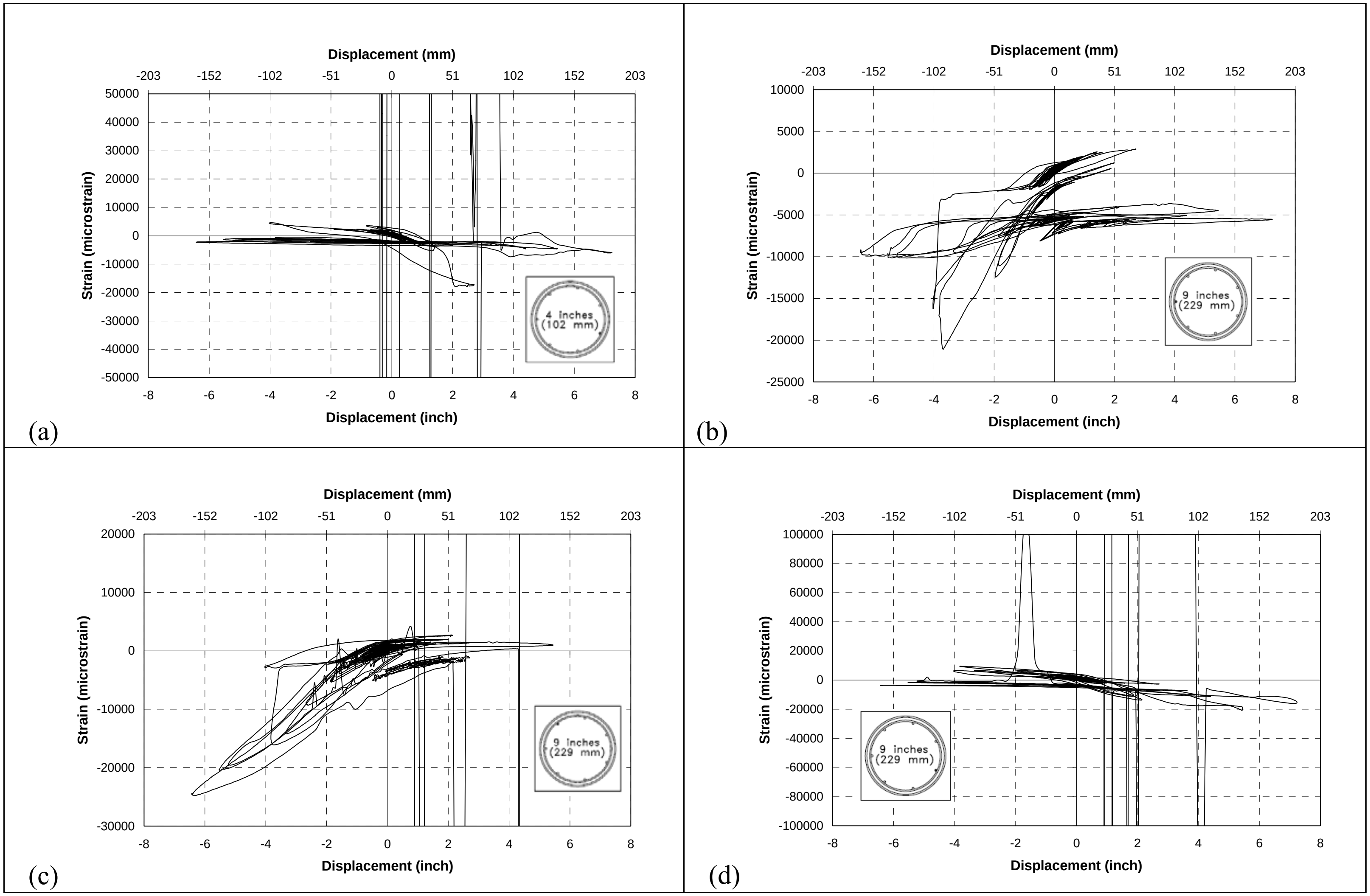

Fig. A-91. a) sg 49, b) sg 51, c) sg 52, d) sg 53 for FRP Column in PEFB

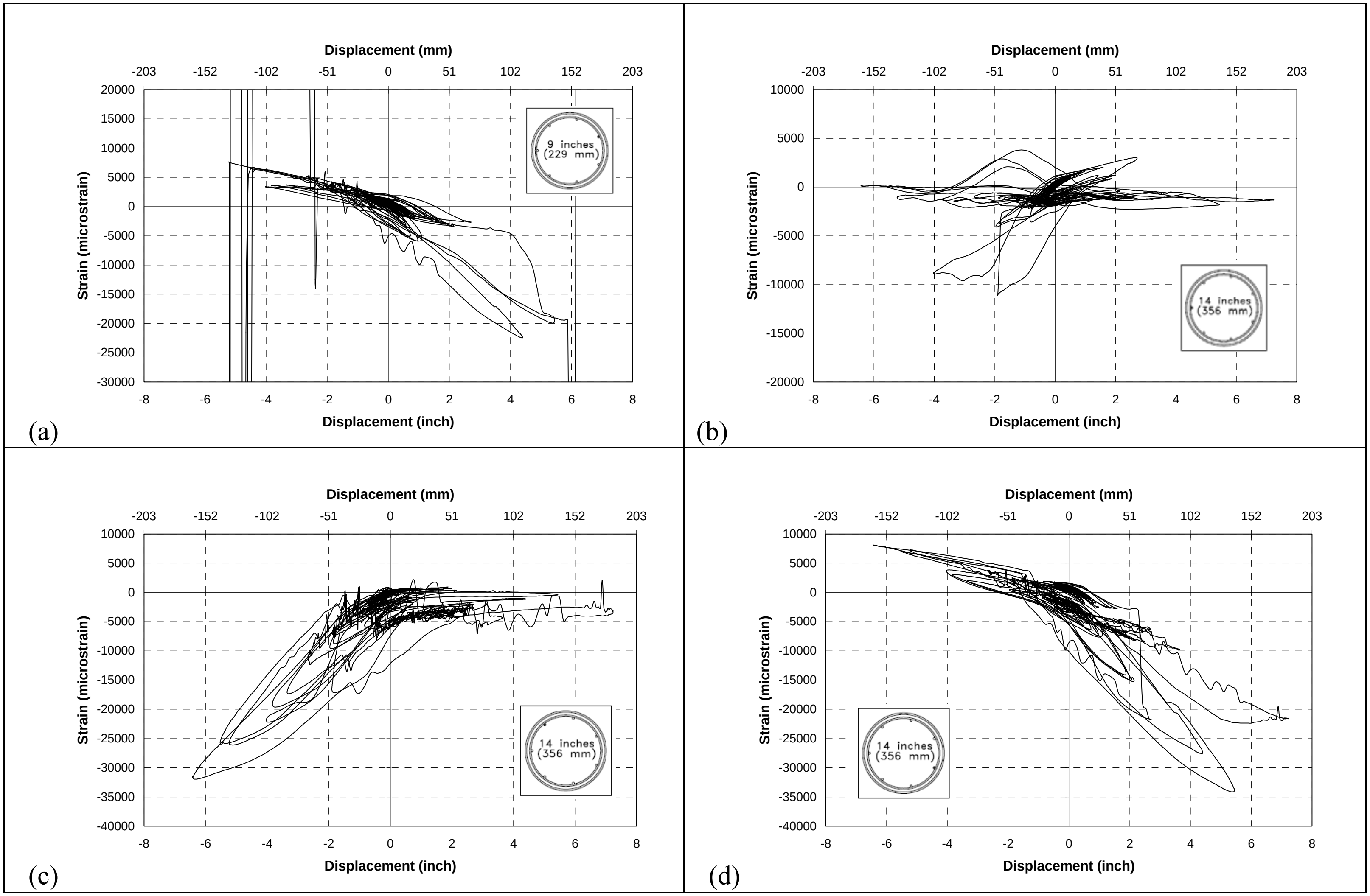

Fig. A-92. a) sg 54, b) sg 55, c) sg 56, d) sg 57 for FRP Column in PEFB

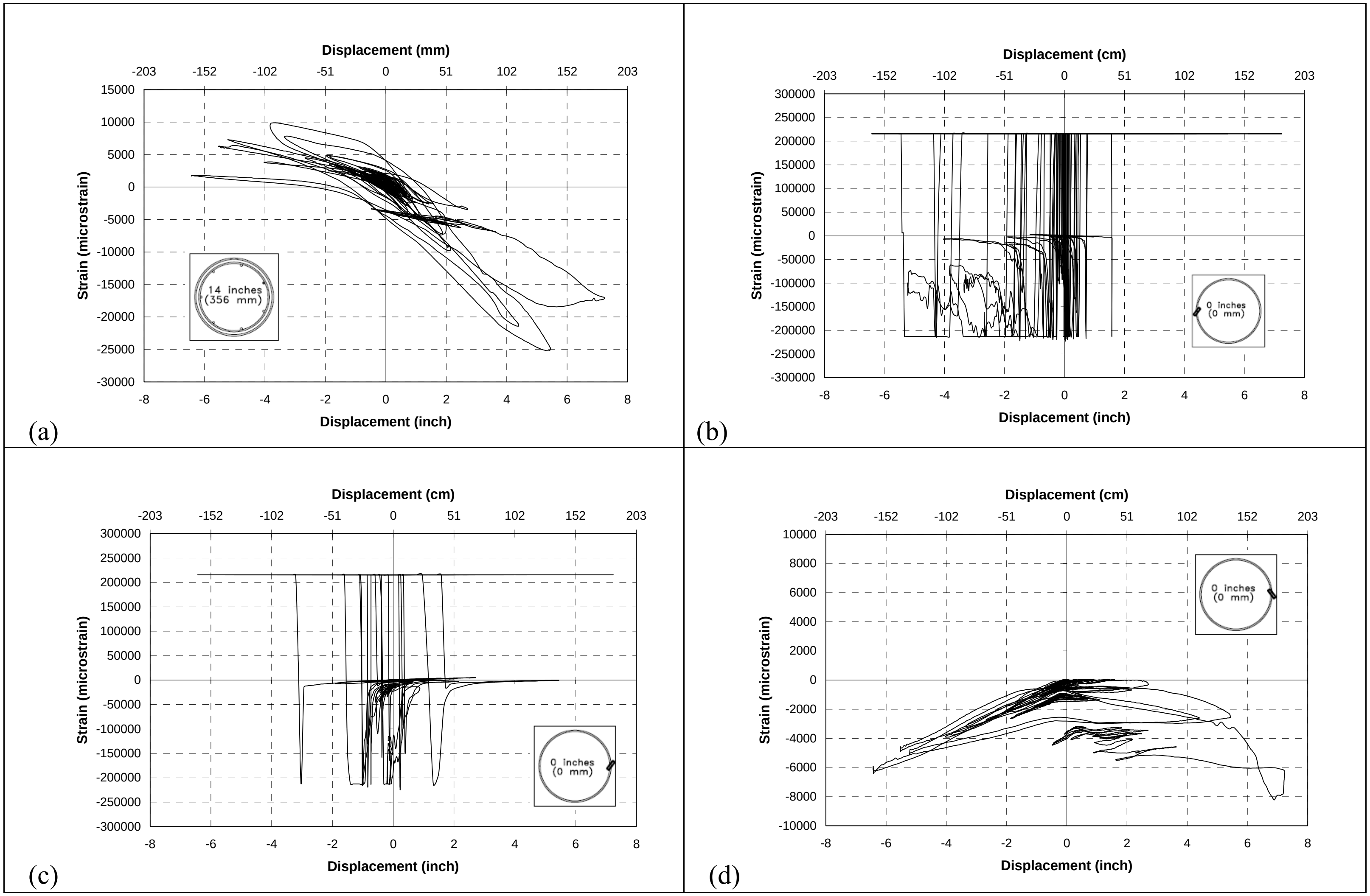

Fig. A-93. a) sg 58, b) sg 64, c) sg 65, d) sg 66 for FRP Column in PEFB

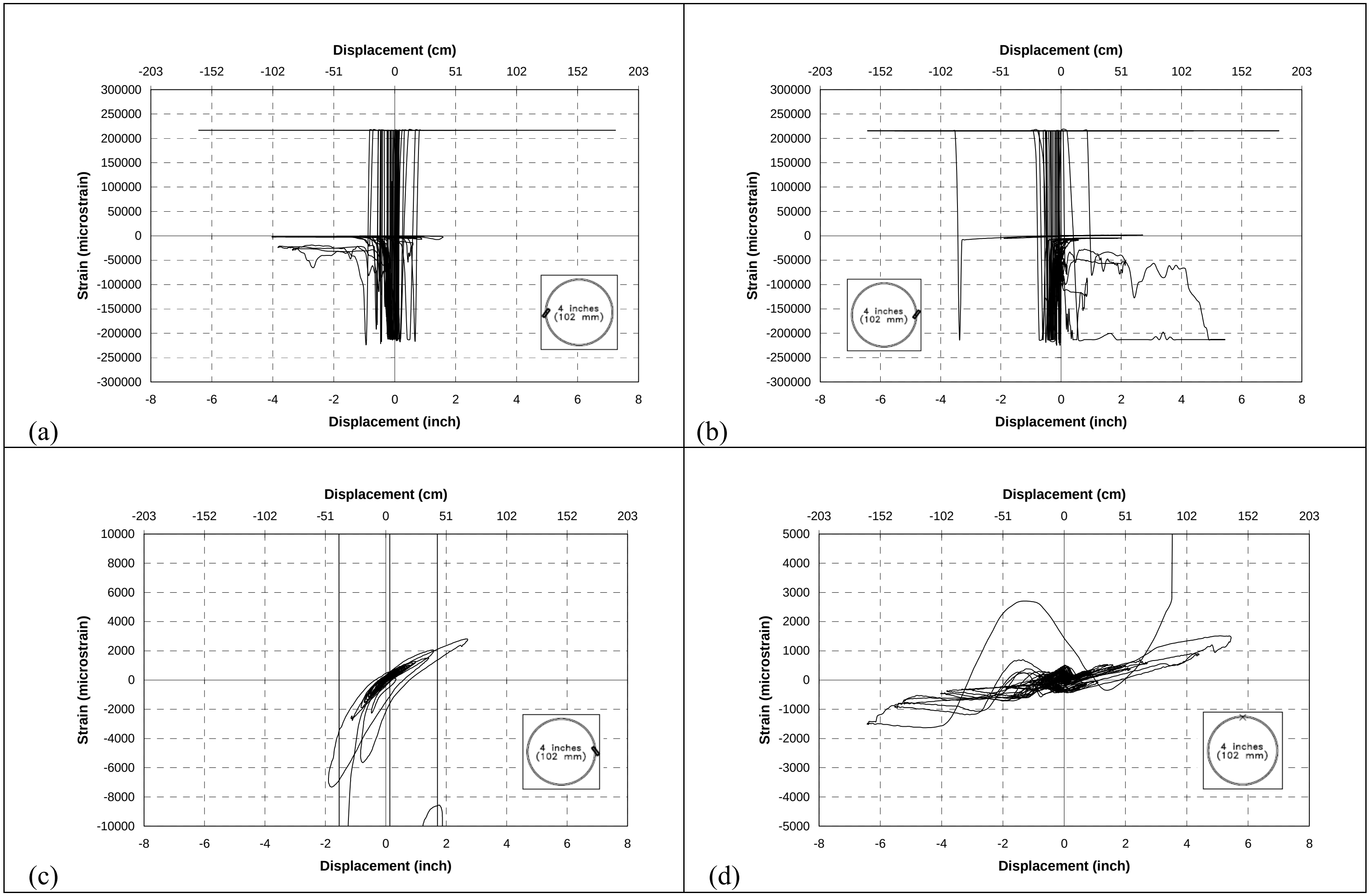

Fig. A-94. a) sg 68, b) sg 69, c) sg 70, d) sg 71,72,73 Rosette, Max. for FRP Column in PEFB

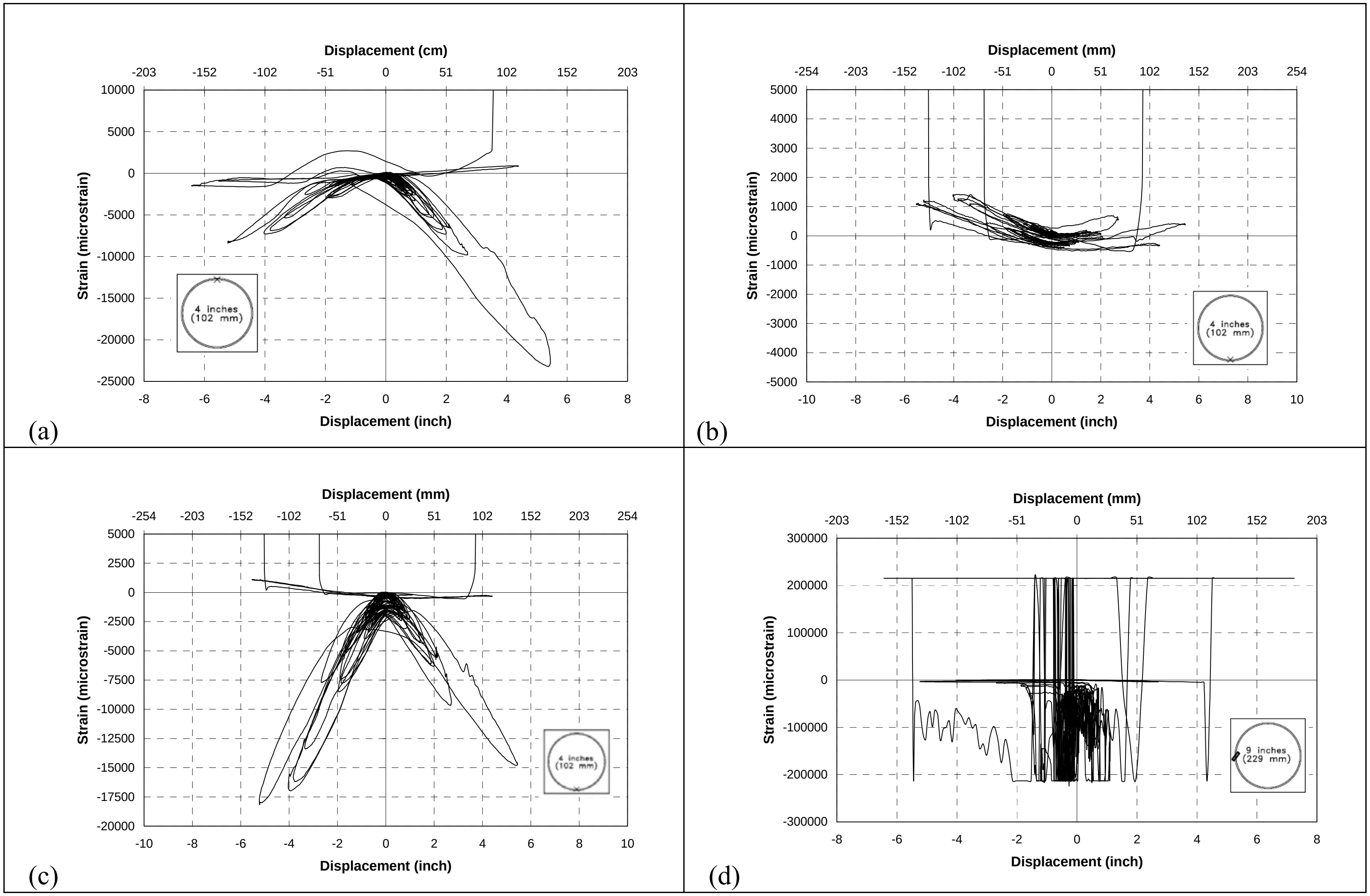

Fig. A-95. a) sg 71,72,73 Rosette, Min. b) sg 74,75,76 Rosette, Max., c) sg 74,75,76 Rosette, Min., d) sg 77, for FRP Column in PEFB

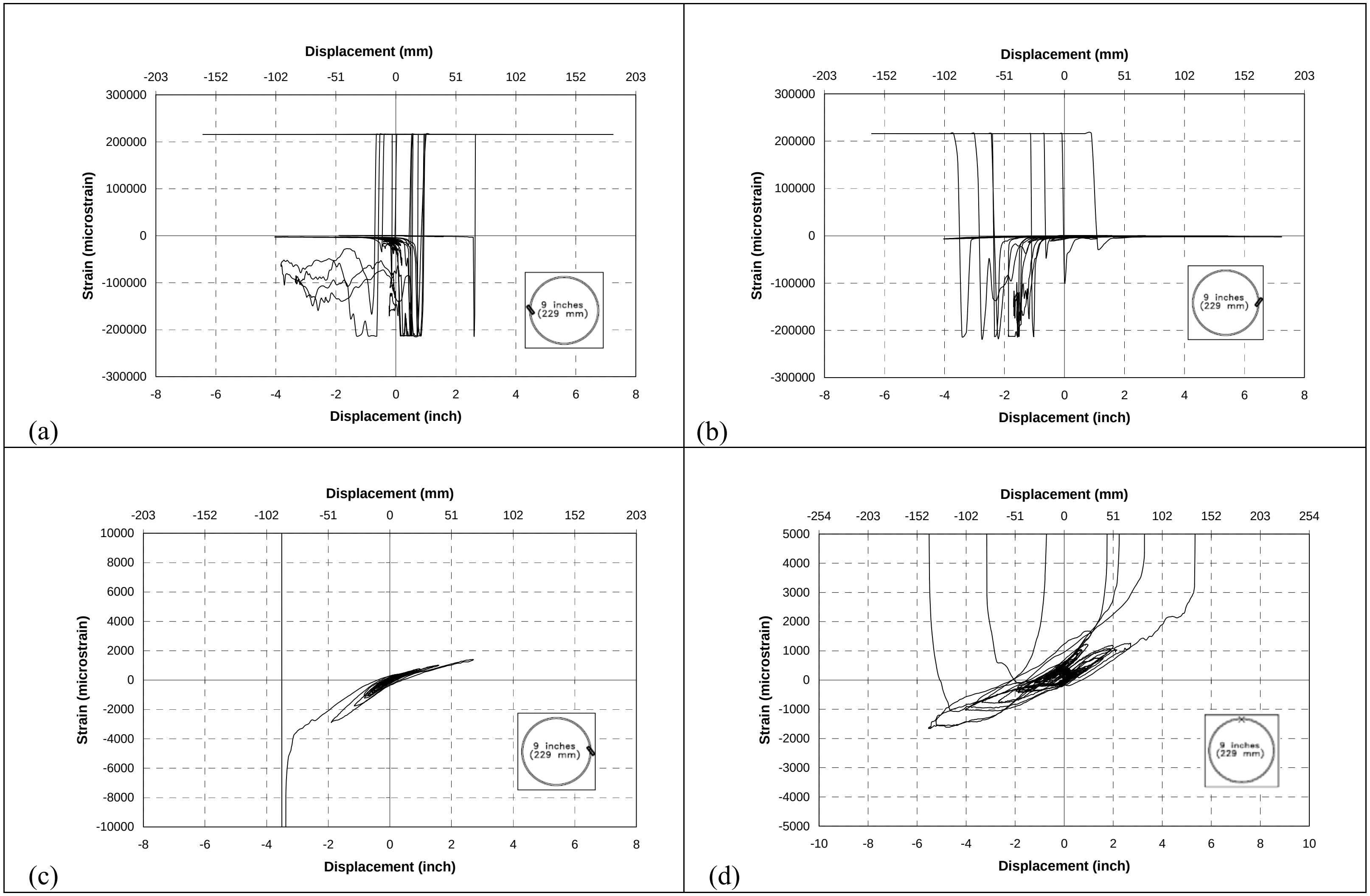

Fig. A-96. a) sg 78, b) sg 79 , c) sg 80, d) sg 81,82,83 Rosette, Max., for FRP Column in PEFB

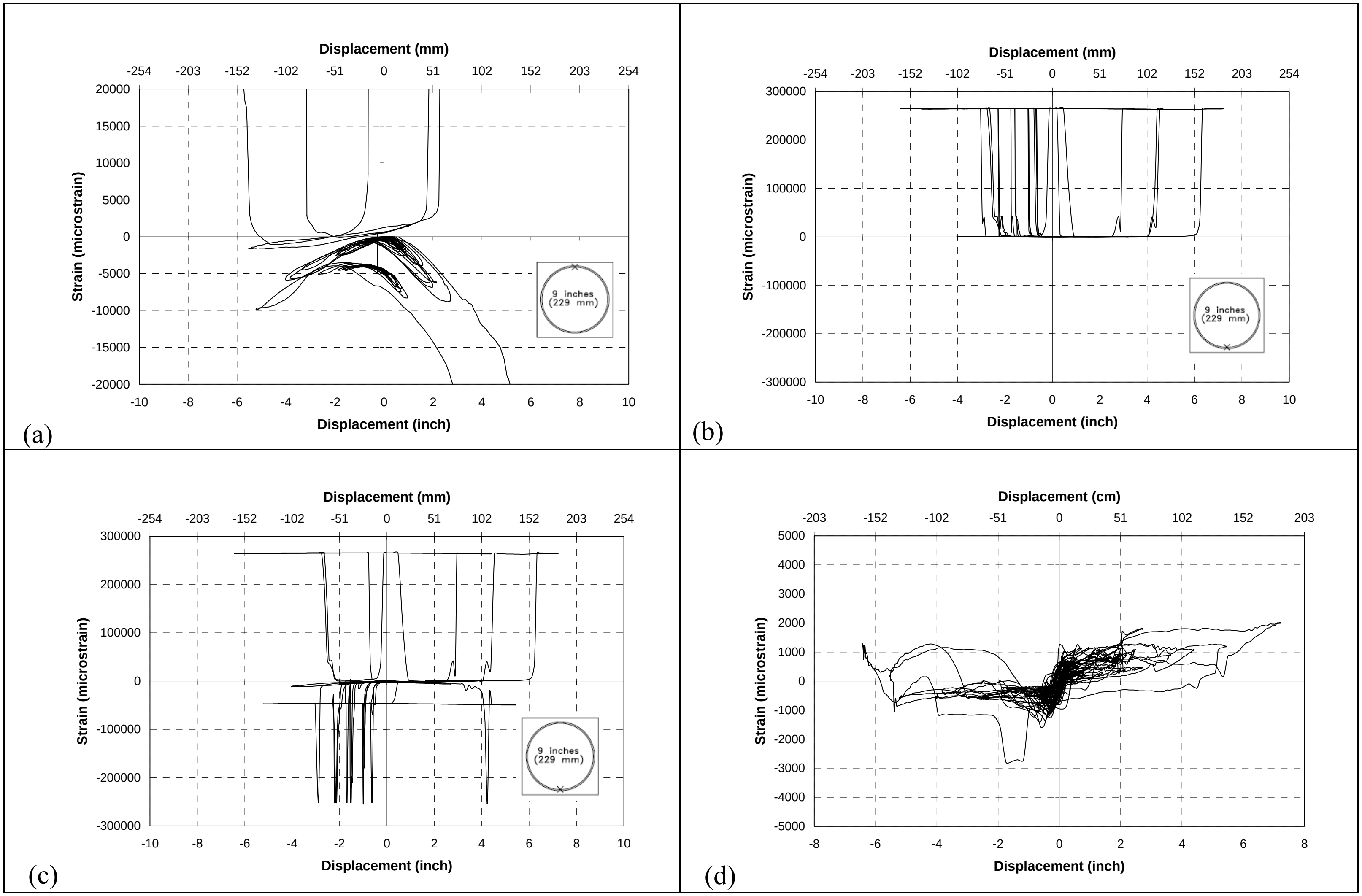

Fig. A-97. a) sg 81,82,83 Rosette, Min b) sg 84,85, 86 Rosette, Max., c) sg 84,85, 86 Rosette, Min., d) sg 87 for FRP Column in PEFB

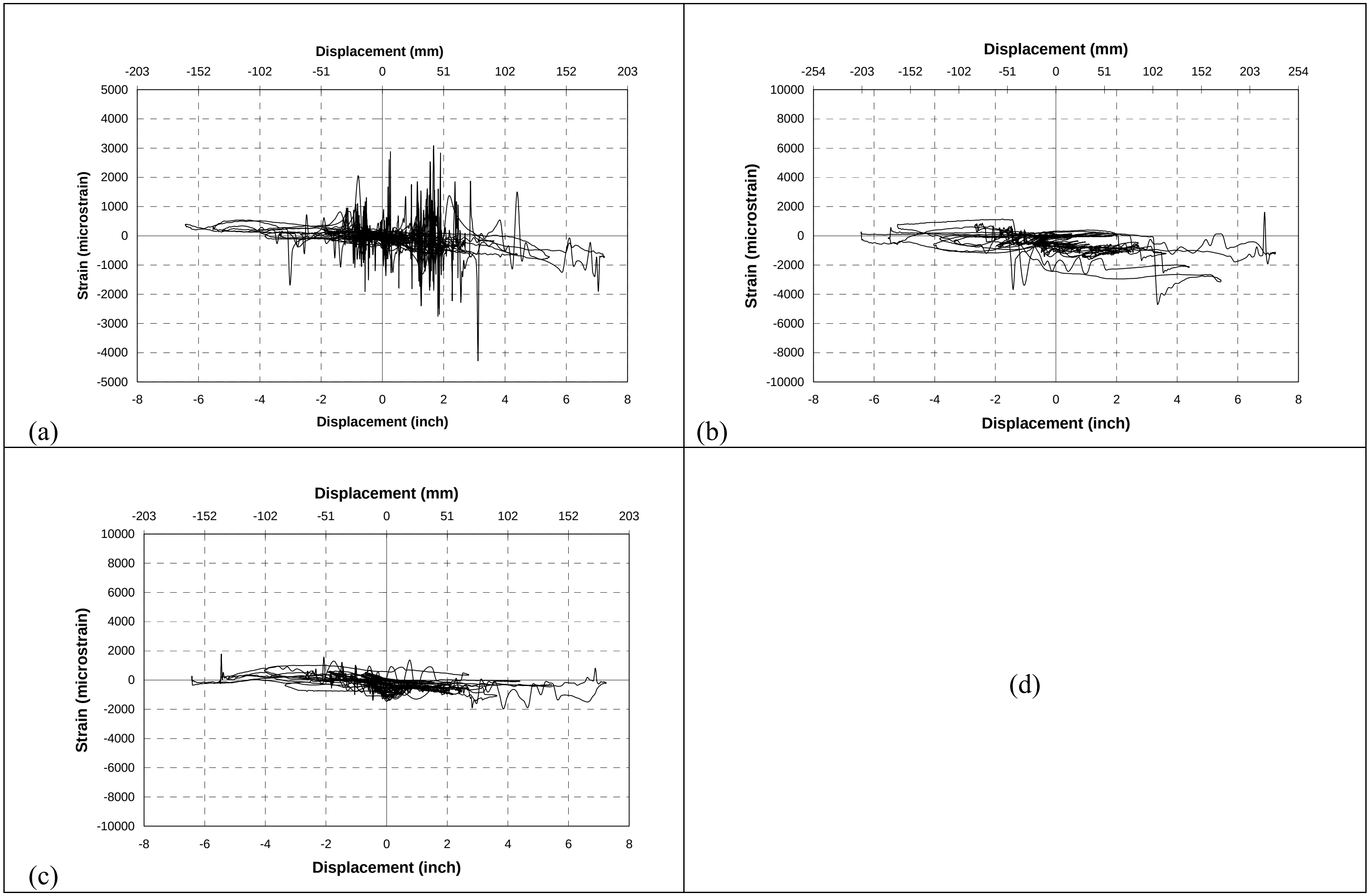

Fig. A-98. a) sg 88, b) sg 89, c) sg 90, on the Steel Pipe Hinges in PEFB

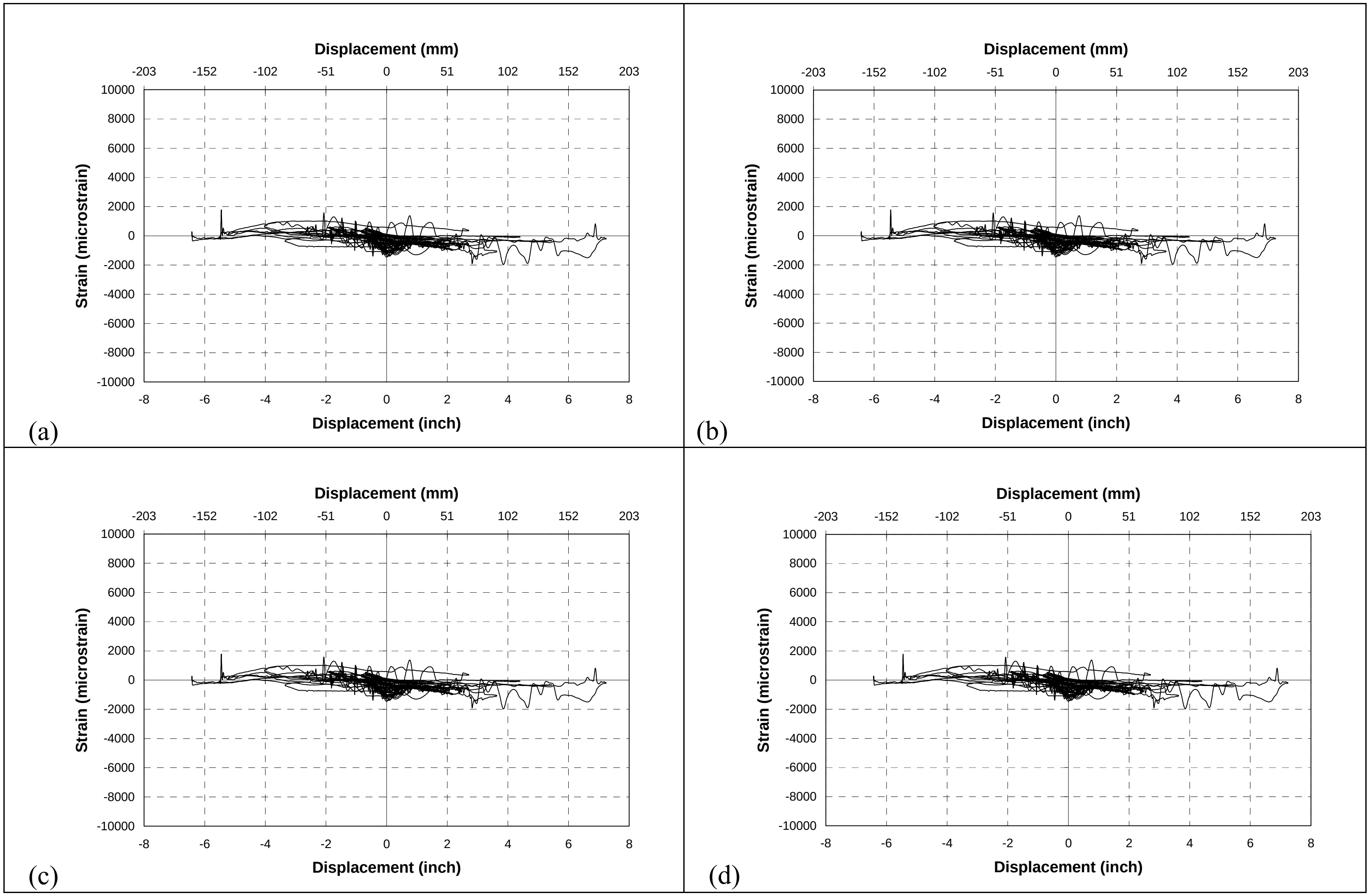

Fig. A-99. a) sg 91, b) sg 93, c) sg 94, d) sg 95 on the Footing Bars in PEFB

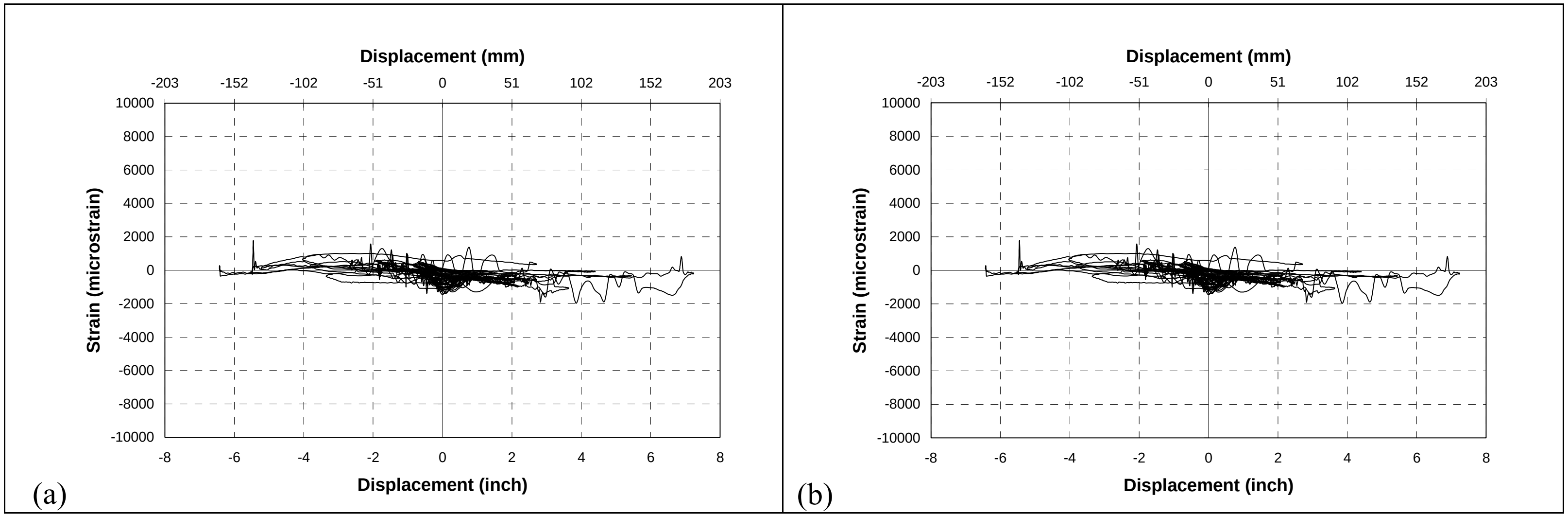

Fig. A-100. a) sg 96, b) sg 98, on the Footing Bars in PEFB

APPENDIX B: CONFINED ECC STRESS-STRAIN MODEL EXAMPLE

B.1. Calculation of Confined ECC Properties

Step 1: Calculate confinement stress f_l'

$$f_l' = \frac{2A_{sp}\, f_y}{d_s s} \qquad \text{Eq. B1}$$

Where:

f_l' = Confinement stress (ksi)

A_{sp} = Transverse steel area (in^2)

f_y =Yield stress of transverse steel (ksi)

d_s =Core diameter (center of spirals to center) (in)

s =Spacing of transverse steel (in)

Step 2: Calculate maximum confined strength f_{ce}'

For $\frac{f_l'}{f_{co}'} \leq 0.035$ $\qquad f_{ce}' = f_{co}'$ $\qquad$ Eq. B2

For $\frac{f_l'}{f_{co}'} > 0.035$ $\qquad f_{ce}' = f_{co}'(-1.25 + 2\sqrt{1 + \frac{10.5 f_l'}{f_{co}'}} - 2\frac{f_l'}{f_{co}'})$ $\qquad$ Eq. B3

Where:

f_l' = Confinement stress (Eq. B1) (ksi)

f_{ce}' = Confined strength (ksi)

f_{co}' = Unconfined strength (ksi)

Step 3: Calculate strain at maximum strength ε_{ce}

$$\varepsilon_{ce} = 0.0025\left[1 + 2.7(\frac{f'_{ce}}{f'_{co}} - 1)\right] \qquad \text{Eq. B4}$$

Where:

f'_{ce} = Confined strength (Eqs. B2 and B3) (ksi)

f'_{co} = Unconfined strength (ksi)

Step 4: Calculate ultimate strength f_{ue}

$$f'_{ue} = 0.4 f'_{ce} \qquad \text{Eq. B5}$$

Where:

f'_{ce} = Confined strength (Eqs. B2 and B3) (ksi)

Step 5: Calculate ultimate strain ε_{ue}

$$\varepsilon_{ue} = 0.004 + 1.4\rho_s f_y \frac{\varepsilon_{sm}}{f'_{ce}} \qquad \text{Eq. B6}$$

Where:

$$\rho_s = \frac{4A_{sp}}{d_s s} \qquad \text{Eq. B7}$$

ρ_s =Volumetric transverse steel ratio

A_{sp} = Transverse steel area (in^2)

d_s =Core diameter (center of spirals to center) (in)

s_h =Spacing of transverse steel (in)

f_y =Yield stress of transverse steel (ksi)

ε_{sm} =Steel strain at maximum tensile stress

f'_{ce} = Confined strength (Eqs. B2 and B3) (ksi)

Step 6: Calculate the entire stress-strain curve

For $0 \le \varepsilon \le \varepsilon_f$ $\qquad f = f'_{ce} \dfrac{\varepsilon}{\varepsilon_{ce}} \dfrac{n}{n-1+\left(\dfrac{\varepsilon}{\varepsilon_{ce}}\right)^n}$ Eq. B8

For $\varepsilon_f \le \varepsilon \le \varepsilon_{ue}$ $\qquad f = 0.4 f'_{ce}$ Eq. B9

Where:

$$\varepsilon_f = \varepsilon_{ce} \times (-0.8Ln(f'_{ce}) + 9.5)$$ Eq. B10

$$n = n_{Mortar} = 0.2 \times 10^{-3} \times f'_{ce} + 2$$ Eq. B11

ε_f = strain in the beginning of stabilized part of the curve (Eq. B10)

n =Material Parameter (Eq. B11)

f'_{ce} = Confined strength (Eqs. B2 and B3) (psi)

ε_{ce} = Strain at maximum strength (Eq. B4)

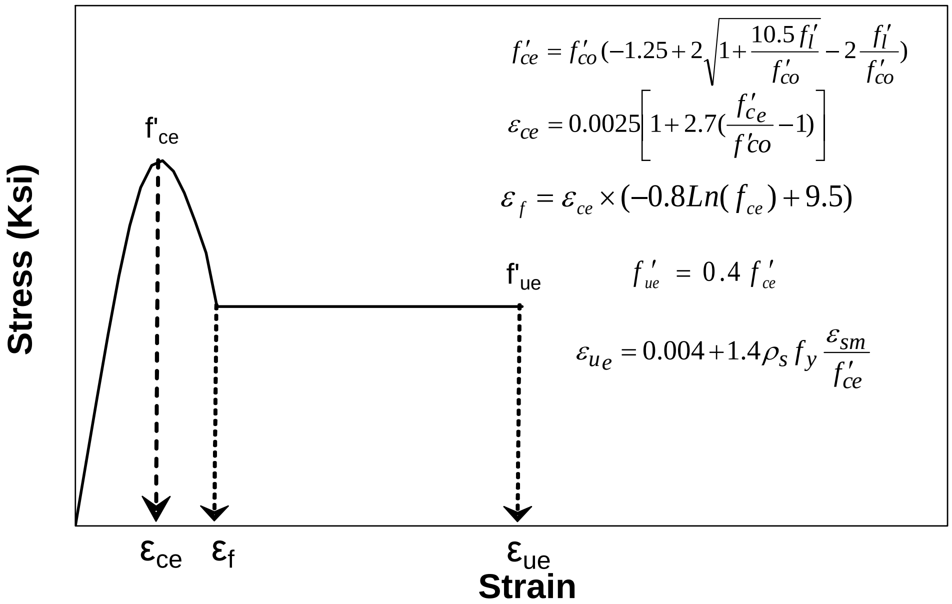

Fig. B-1. Confined ECC Stress-Strain Relationships Parameters

B.2. Example

The proposed equations to calculate stress- strain parameters of confined ECC are presented in the following example. The section diameter is 16 in. (406 mm) with 0.5 in. (13 mm) cover on the spirals. The spirals are #3 bars with 0.375 in. (9 mm) diameter. The spirals spacing is 2 in. (51 mm). Unconfined ECC strength is 5 ksi (34.5 MPa) and yield stress of transverse bars is 60 ksi (413.7 MPa).

D =16 in. (406 mm)	Cover= 0.5 in. (13 mm)
d_{sp} = 0.375 in. (9 mm)	A_{sp} =0.11 in2 (71 mm^2)
f_y = 60 ksi (413.7 MPa)	f'_{co} =5 ksi (34.5 MPa)
s_h = 2 in. (51 mm)	ε_{sm} =0.1

Step 1: Calculate confinement stress f'_l

d_s = core diameter= $16 - 2 \times 0.5 - 0.375 = 14.625\ in.$ (371 mm)

$$f'_l = \frac{2A_{sp}\ f_y}{d_s s} = \frac{2 \times 0.11 \times 60}{14.625 \times 2} = 0.45\ \text{ksi (3.1 MPa)}$$

Step 2: Calculate maximum confined strength f'_{ce}

$$\frac{f'_l}{f'_{co}} = \frac{0.45}{5} = 0.09$$

Check if:

$$\frac{f'_l}{f'_{co}} > 0.035 \text{ or } \frac{f'_l}{f'_{co}} \le 0.035$$

Therefore, using Eq. B3

For $\frac{f'_l}{f'_{co}} > 0.035$

$$f'_{ce} = f'_{co}(-1.25 + 2\sqrt{1 + \frac{10.5 f'_l}{f'_{co}}} - 2\frac{f'_l}{f'_{co}})$$

$$f'_{ce} = 5(-1.25 + 2\sqrt{1 + \frac{10.5 \times 0.45}{5}} - 2 \times \frac{0.45}{5}) = 6.8\,ksi\ \text{(46.8 MPa)}$$

Step 3: Calculate strain at maximum strength ε_{ce} from Eq. B4,

$$\varepsilon_{ce} = 0.0025\left[1 + 2.7(\frac{f'_{ce}}{f'_{co}} - 1)\right] = 0.0025\left[1 + 2.7(\frac{6.8}{5} - 1)\right] = 0.0049$$

Step 4: Calculate ultimate strength f_{ue} from Eq. B5

$$f'_{ue} = 0.4 f'_{ce} = 0.4 \times 6.8 = 2.72 ksi \ \ (18.7\ \text{MPa})$$

Step 5: Calculate ultimate strain ε_{ue} from Eqs. B6 and B7

$$\rho_s = \frac{4A_{sp}}{d_s s} = \frac{4 \times 0.11}{14.625 \times 2} = 0.015$$

$$\varepsilon_{ue} = 0.004 + 1.4\rho_s f_y \frac{\varepsilon_{sm}}{f'_{ce}} = 0.004 + 1.4 \times 0.015 \times 60 \times \frac{0.1}{6.8} = 0.022$$

Step 6: Calculate the entire stress-strain curve

Confined ECC stresses are calculated from Eq. B8 for strains up to ε_f. For strains exceeding ε_f, Eq. B9 can be used to calculate the stress.

For $0 \le \varepsilon \le \varepsilon_f$ $\quad f = f'_{ce} \dfrac{\varepsilon}{\varepsilon_{ce}} \dfrac{n}{n - 1 + \left(\dfrac{\varepsilon}{\varepsilon_{ce}}\right)^n} = 6.8 \times \dfrac{\varepsilon}{0.0049} \times \dfrac{3.36}{3.36 - 1 + \left(\dfrac{\varepsilon}{0.0049}\right)^{3.36}}$

For $\varepsilon_f \le \varepsilon \le \varepsilon_{ue}$ $\quad f = 0.4 f'_{ce} = 0.4 \times 6.8 = 2.72 ksi$ (18.7 MPa)

Where:

ε_f and n are calculated from Eqs. B10 and B11, respectively.

$$\varepsilon_f = \varepsilon_{ce} \times (-0.8 Ln(f'_{ce}) + 9.5) = 0.0049 \times (-0.8 Ln(6.8 \times 1000) + 9.5) = 0.012$$

$$n = n_{Mortar} = 0.2 \times 10^{-3}\ f'_{ce} + 2 = 0.2 \times 10^{-3} \times 6.8 \times 1000 + 2 = 3.36$$

Figure B-2 displays the stress-strain results for this example.