

1. SPG 응력산정

※ 외측거더 중앙부

① 합 성 전

$$I_s' = A_s \times Y^2 + \sum I_s = 25059574709.6 + 6513340836.53333 = 31572915546 \text{mm}^4$$

$$\delta_s = \sum (A \times Y) / A_s = -8577976 / 46438 = -184.719 \text{mm}$$

$$I_s = I_s' - A_s \times \delta_s^2 = 31572915546 - 46438 \times (-184.719)^2 = 29988399488 \text{mm}^4$$

$$Y_{su} = H/2 + T_u - \delta_s = 1940/2 + 21.4 - (-184.719) = 1176.119 \text{mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1176.119 - 2004.2 = -828.081 \text{mm}$$

$$F = b \times h = ((UL^2 + UR^2 + B^2)/2 + T_w) \times (H + T_u/2 + T_l/2) = 799390.735 \text{mm}^2$$

$$f_{su} = M_s \times Y_{su} / I_s = 77.114 \text{MPa}$$

$$f_{sl} = M_s \times Y_{sl} / I_s = -54.295 \text{MPa}$$

$$v = S_s / A(\text{Web}) + M_{st} / (2 \times F \times T_w) = 0.421 \text{MPa}$$

② 합 성 후

$$A_v = A_s + A_c/n = 143313 \text{mm}^2$$

$$I_c/n = 504557292 \text{mm}^4$$

$$d_v = Y_{su} - T_u + T_h + T_c/2 = 1329.719 \text{mm}$$

$$d_{vc} = d_v \times A_s / (A_c/n + A_s) = 430.872 \text{mm}$$

$$d_{vs} = d_v - d_{vc} = 898.847 \text{mm}$$

$$Y_{vcu} = d_{vc} + T_c/2 = 555.872 \text{mm}$$

$$Y_{vcl} = Y_{vcu} - T_c = 305.872 \text{mm}$$

$$Y_{vsu} = Y_{vcu} - H/2 + T_u = 277.272 \text{mm}$$

$$Y_{vsl} = Y_{vsu} - (H + T_u + T_l) = -1726.928 \text{mm}$$

$$I_v = I_s + I_c/n + A_s \times d_{vs}^2 + A_c/n \times d_{vc}^2 = 85996330752 \text{mm}^4$$

$$F_v = b \times h_v = ((UL^2 + UR^2 + B^2)/2 + T_w) \times (H + (T_u + T_c/n)/2 + T_l/2) = 805724 \text{mm}^2$$

$$f_{vcu} = M_{sc} \times Y_{vcu} / (n \times I_v) = 1.358 \text{MPa}$$

$$f_{vcl} = M_{sc} \times Y_{vcl} / (n \times I_v) = 0.747 \text{MPa}$$

$$f_{vsu} = M_{sc} \times Y_{vsu} / I_v = 5.42 \text{MPa}$$

$$f_{vsl} = M_{sc} \times Y_{vsl} / I_v = -33.758 \text{MPa}$$

$$v = S_{sc} / A(\text{Web}) + M_{sct} / (2 \times F_v \times T_w) = 1.146 \text{MPa}$$

③ 활 하 중

$$f_{vcu} = M_v \times Y_{vcu} / (n \times I_v) = 0.961 \text{MPa}$$

$$f_{vcl} = M_v \times Y_{vcl} / (n \times I_v) = 0.529 \text{MPa}$$

$$f_{vsu} = M_v \times Y_{vsu} / I_v = 3.834 \text{MPa}$$

$$f_{vsl} = M_v \times Y_{vsl} / I_v = -23.88 \text{MPa}$$

$$v = S_v / A(\text{Web}) + M_{vt} / (2 \times F_v \times T_w) = 4.169 \text{MPa}$$

※ 내측거더 중앙부

① 합 성 전

$$I_s' = A_s \times Y^2 + \sum I_s = 25059574709.6 + 6513340836.53333 = 31572915546 \text{mm}^4$$

$$\delta_s = \sum (A \times Y) / A_s = -8577976 / 46438 = -184.719 \text{mm}$$

$$I_s = I_s' - A_s \times \delta_s^2 = 31572915546 - 46438 \times (-184.719)^2 = 29988399488 \text{mm}^4$$

$$Y_{su} = H/2 + T_u - \delta_s = 1940/2 + 21.4 - (-184.719) = 1176.119 \text{mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1176.119 - 2004.2 = -828.081 \text{mm}$$

$$F = b \times h = ((UL_2 + UR_2 + B_2)/2 + T_w) \times (H + T_u/2 + T_l/2) = 799390.735 \text{mm}^2$$

$$f_{su} = M_s \times Y_{su} / I_s = 61.722 \text{MPa}$$

$$f_{sl} = M_s \times Y_{sl} / I_s = -43.457 \text{MPa}$$

$$v = S_s / A(\text{Web}) + M_{st} / (2 \times F \times T_w) = 0.255 \text{MPa}$$

② 합 성 후

$$A_v = A_s + A_c/n = 146438 \text{mm}^2$$

$$I_c/n = 5208333333 \text{mm}^4$$

$$d_v = Y_{su} - T_u + T_h + T_c/2 = 1329.719 \text{mm}$$

$$d_{vc} = d_v \times A_s / (A_c/n + A_s) = 421.677 \text{mm}$$

$$d_{vs} = d_v - d_{vc} = 908.042 \text{mm}$$

$$Y_{vcu} = d_{vc} + T_c/2 = 546.677 \text{mm}$$

$$Y_{vcl} = Y_{vcu} - T_c = 296.677 \text{mm}$$

$$Y_{vsu} = Y_{vcu} - H/2 + T_u = 268.077 \text{mm}$$

$$Y_{vsl} = Y_{vsu} - (H + T_u + T_l) = -1736.123 \text{mm}$$

$$I_v = I_s + I_c/n + A_s \times d_{vs}^2 + A_c/n \times d_{vc}^2 = 86580383287 \text{mm}^4$$

$$F_v = b \times h_v = ((UL_2 + UR_2 + B_2)/2 + T_w) \times (H + (T_u + T_c/n)/2 + T_l/2) = 805724 \text{mm}^2$$

$$f_{vcu} = M_{sc} \times Y_{vcu} / (n \times I_v) = 0.96 \text{MPa}$$

$$f_{vcl} = M_{sc} \times Y_{vcl} / (n \times I_v) = 0.521 \text{MPa}$$

$$f_{vsu} = M_{sc} \times Y_{vsu} / I_v = 3.767 \text{MPa}$$

$$f_{vsl} = M_{sc} \times Y_{vsl} / I_v = -24.396 \text{MPa}$$

$$v = S_{sc} / A(\text{Web}) + M_{sct} / (2 \times F_v \times T_w) = 0.628 \text{MPa}$$

③ 활 하 중

$$f_{vcu} = M_v \times Y_{vcu} / (n \times I_v) = 0.815 \text{MPa}$$

$$f_{vcl} = M_v \times Y_{vcl} / (n \times I_v) = 0.442 \text{MPa}$$

$$f_{vsu} = M_v \times Y_{vsu} / I_v = 3.197 \text{MPa}$$

$$f_{vsl} = M_v \times Y_{vsl} / I_v = -20.705 \text{MPa}$$

$$v = S_v / A(\text{Web}) + M_{vt} / (2 \times F_v \times T_w) = 5.445 \text{MPa}$$

※ 외측거더 지점부

① 합 성 전

$$\begin{aligned}
 I_s' &= A_s \times Y^2 + \sum I_s = 45962666709.6 + 16409378503.2 = 62372045213 \text{mm}^4 \\
 \delta_s &= \sum (A \times Y) / A_s = -11573976 / 53928 = -214.619 \text{mm} \\
 I_s &= I_s' - A_s \times \delta_s^2 = 62372045213 - 53928 \times (-214.619)^2 = 59888050609 \text{mm}^4 \\
 Y_{su} &= H/2 + T_u - \delta_s = 2640/2 + 21.4 - (-214.619) = 1556.019 \text{mm} \\
 Y_{sl} &= Y_{su} - (H + T_u + T_l) = 1556.019 - 2704.2 = -1148.181 \text{mm} \\
 F &= b \times h = ((UL2 + UR2 + B2)/2 + T_w) \times (H + T_u/2 + T_l/2) = 1083136 \text{mm}^2 \\
 f_{su} &= M_s \times Y_{su} / I_s = -105.533 \text{MPa} \\
 f_{sl} &= M_s \times Y_{sl} / I_s = 77.872 \text{MPa} \\
 v &= S_s / A(\text{Web}) + M_{st} / (2 \times F \times T_w) = 18.137 \text{MPa}
 \end{aligned}$$

② 합 성 후

$$\begin{aligned}
 A_v &= A_s + A_r = 77738 \text{mm}^2 \\
 d &= Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \times A_{ru} / A_r = 1709.619 \text{mm} \\
 d_r &= d \times A_s / (A_s + A_r) = 1185.988 \text{mm} \\
 d_s &= d - d_r = 523.631 \text{mm} \\
 Y_{vru} &= d_r + (T_c - t_{cu} - t_{cl}) \times A_{rl} / A_r = 1250.988 \text{mm} \\
 Y_{vrl} &= d_r - (T_c - t_{cu} - t_{cl}) \times A_{ru} / A_r = 1120.988 \text{mm} \\
 Y_{vsu} &= Y_{vrl} - t_{cl} - T_h + T_u = 1032.388 \text{mm} \\
 Y_{vsl} &= Y_{vsu} - (H + T_u + T_l) = -1671.812 \text{mm} \\
 I_{rv} &= I_s + A_s \times d_s^2 + A_r \times d_r^2 = 108164910911 \text{mm}^4 \\
 F_v &= b \times h_v = ((UL2 + UR2 + B2)/2 + T_w) \times (H + (T_u + T_c/n)/2 + T_l/2) = 1089469 \text{mm}^2 \\
 f_{vru} &= M_{sc} \times Y_{vru} / I_{rv} = -39.982 \text{MPa} \\
 f_{vrl} &= M_{sc} \times Y_{vrl} / I_{rv} = -35.827 \text{MPa} \\
 f_{vsu} &= M_{sc} \times Y_{vsu} / I_{rv} = -32.995 \text{MPa} \\
 f_{vsl} &= M_{sc} \times Y_{vsl} / I_{rv} = 53.431 \text{MPa} \\
 v &= S_{sc} / A(\text{Web}) + M_{sct} / (2 \times F_v \times T_w) = 15.848 \text{MPa}
 \end{aligned}$$

③ 활 하 중

$$\begin{aligned}
 f_{vru} &= M_v \times Y_{vru} / I_{rv} = -17.23 \text{MPa} \\
 f_{vrl} &= M_v \times Y_{vrl} / I_{rv} = -15.44 \text{MPa} \\
 f_{vsu} &= M_v \times Y_{vsu} / I_{rv} = -14.22 \text{MPa} \\
 f_{vsl} &= M_v \times Y_{vsl} / I_{rv} = 23.027 \text{MPa} \\
 v &= S_v / A(\text{Web}) + M_{vt} / (2 \times F_v \times T_w) = 7.477 \text{MPa}
 \end{aligned}$$

※ 내측거더 지점부

① 합 성 전

$$I_s' = A_s \times Y^2 + \sum I_s = 45962666709.6 + 16409378503.2 = 62372045213 \text{ mm}^4$$

$$\delta s = \sum (A \times Y) / A_s = -11573976 / 53928 = -214.619 \text{ mm}$$

$$I_s = I_s' - A_s \times \delta s^2 = 62372045213 - 53928 \times (-214.619)^2 = 59888050609 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2640/2 + 21.4 - (-214.619) = 1556.019 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1556.019 - 2704.2 = -1148.181 \text{ mm}$$

$$F = b \times h = ((UL/2 + UR/2 + B/2) / 2 + T_w) \times (H + T_u/2 + T_l/2) = 1083136 \text{ mm}^2$$

$$f_{su} = M_s \times Y_{su} / I_s = -78.205 \text{ MPa}$$

$$f_{sl} = M_s \times Y_{sl} / I_s = 57.708 \text{ MPa}$$

$$\nu = S_s / A(\text{Web}) + M_{st} / (2 \times F \times T_w) = 10.829 \text{ MPa}$$

② 합 성 후

$$A_v = A_s + A_r = 78364 \text{ mm}^2$$

$$d = Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \times A_{ru} / A_r = 1709.619 \text{ mm}$$

$$d_r = d \times A_s / (A_s + A_r) = 1176.514 \text{ mm}$$

$$d_s = d - d_r = 533.105 \text{ mm}$$

$$Y_{vru} = d_r + (T_c - t_{cu} - t_{cl}) \times A_{rl} / A_r = 1241.514 \text{ mm}$$

$$Y_{vrl} = d_r - (T_c - t_{cu} - t_{cl}) \times A_{ru} / A_r = 1111.514 \text{ mm}$$

$$Y_{vsu} = Y_{vrl} - t_{cl} - T_h + T_u = 1022.914 \text{ mm}$$

$$Y_{vsl} = Y_{vsu} - (H + T_u + T_l) = -1681.286 \text{ mm}$$

$$I_{rv} = I_s + A_s \times d_s^2 + A_r \times d_r^2 = 109038388313 \text{ mm}^4$$

$$F_v = b \times h_v = ((UL/2 + UR/2 + B/2) / 2 + T_w) \times (H + (T_u + T_c/n) / 2 + T_l/2) = 1089469 \text{ mm}^2$$

$$f_{vru} = M_{sc} \times Y_{vru} / I_{rv} = -25.802 \text{ MPa}$$

$$f_{vrl} = M_{sc} \times Y_{vrl} / I_{rv} = -23.1 \text{ MPa}$$

$$f_{vsu} = M_{sc} \times Y_{vsu} / I_{rv} = -21.259 \text{ MPa}$$

$$f_{vsl} = M_{sc} \times Y_{vsl} / I_{rv} = 34.941 \text{ MPa}$$

$$\nu = S_{sc} / A(\text{Web}) + M_{sct} / (2 \times F_v \times T_w) = 8.739 \text{ MPa}$$

③ 활 하 중

$$f_{vru} = M_v \times Y_{vru} / I_{rv} = -15.87 \text{ MPa}$$

$$f_{vrl} = M_v \times Y_{vrl} / I_{rv} = -14.208 \text{ MPa}$$

$$f_{vsu} = M_v \times Y_{vsu} / I_{rv} = -13.075 \text{ MPa}$$

$$f_{vsl} = M_v \times Y_{vsl} / I_{rv} = 21.491 \text{ MPa}$$

$$\nu = S_v / A(\text{Web}) + M_{vt} / (2 \times F_v \times T_w) = 8.006 \text{ MPa}$$

2. SPG 재하시험 계산 변형율 산정

1) 발생모멘트 M (kN.m)

구분	LC1	LC2	LC3	LC4
G1	513.52	281.40	443.81	252.97
G2	394.62	394.62	315.22	315.22
G3	49.29	281.40	62.12	252.97

$$I = 95067786663 \text{mm}^4, y = 940.07 \text{mm}$$

$$\text{변형율 } (\mu \epsilon) = M/I \times y / 0.205$$

2) 발생변형율 ($\mu \epsilon$)

구분	LC1	LC2	LC3	LC4
G1	24.770	13.574	21.408	12.202
G2	19.035	19.035	15.205	15.205
G3	2.378	13.574	2.996	12.202

3. RCB 재하시험 계산 변형율 산정

1) 단면특성 산정

- R.C Box 단면특성

$$A_c = 5.1320 \text{m}^2, I_c = 2.4795 \text{m}^4, y_c = 1.0448 \text{m}$$

- 보강강관 단면특성

$$A_s = 0.006 \times 6.4 \times 8 = 0.3072 \text{m}^2, I_s = 1.152 \times 10^{-7} \text{m}^4, y_s = 0.003 \text{m}$$

- 합성단면특성

$$A_v = 5.4392, I_v = 2.7978 \text{m}^4, y_v = 0.9917 \text{m}$$

2) 발생모멘트

$$\text{LC 1,2 : } 1244.16 \text{kN.m, LC 3,4 : } 673.90 \text{kN.m}$$

3) 변형율

$$M/I_v \times y_v \times n / 0.205$$

$$\text{LC 1,2 : } 1244.16 / 2.7978 \times 0.9917 / 1000 \times 8 / 0.205 = 17.210 \mu \epsilon$$

$$\text{LC 3,4 : } 673.9 / 2.7978 \times 0.9917 / 1000 \times 8 / 0.205 = 9.322 \mu \epsilon$$