

남천교(대구 3@55, S1~S3)-상부구조

1. 설 계 조 건

1) 교량 제원

- | | | | | | | |
|-----|-----------|---|-------------------------|---|-----------|---|
| (1) | 교 량 명 | : | 남천교(대구) | | | |
| (3) | 교 량 형 식 | : | Steel Box Girder교 | | | |
| (4) | 교 량 연 장 | : | 3@55 = 165.0m | | | |
| (5) | 교 량 폭 원 | : | B = 12.150 | m | | |
| (7) | 사 각(Skew) | : | 90.000 | ° | | |
| (6) | Girder 제원 | : | B = 2.500 | m | H = 2.600 | m |
| (2) | 교 량 등 급 | : | 1 등급 (DB-24 및 DL-24 적용) | | | |

(10) 사용재료 및 물리적 특성치

① 강재

■ 사 용 재 료

주 부 재	SM490
부 부 재	SM400
강재 탄성계수 (E_{st})	205,000 MPa
강재의 전단탄성계수 (G)	79,000 MPa

■ 허용 응력 (MPa)

(도.설.해 3.3.2.1)

강 종		SS 400 SM 400 SMA400	SM 490	SM490Y SM 520 SMA490	SM 570 SMA570	HSB500	HSB600	HSB800
응력 종류, 판두께 (mm)								
축방향 인장응력 및 휨 인장응력	40 이하	140	190	215	270	230	270	380
	40 초과 75 이하	130	175 (190)	200 (215)	260 (270)			
	75 초과 100이하			195 (215)	250 (270)			

강 종		SS 400 SM 400 SMA400	SM 490	SM490Y SM 520 SMA490	SM 570 SMA570	HSB500	HSB600	HSB800
응력 종류, 판두께 (mm)								
㉠ 휨 압축응력	40 이하	140	190	215	270	230	270	380
	40 초과 75 이하	130	175 (190)	200 (215)	260 (270)			
	75 초과 100이하			195 (215)	250 (270)			
전단응력	40 이하	80	110	125	155	135	155	220
	40 초과 75 이하	75	100 (110)	115 (125)	150 (155)			
	75 초과 100이하			115 (125)	145 (155)			
지압응력 (강판과 강판 사이)	40 이하	210	285	325	405	345	405	570
	40 초과 75 이하	195	265 (285)	300 (325)	390 (405)			
	75 초과 100이하			295 (325)	375 (405)			

※ TMC 강재일 경우에는 ()안의 값을 적용한다.

압축플랜지가 콘크리트 바닥판 등에 직접 고정되어 있는 경우, 상자형 단면, π형 단면과 같이 횡자굴이 일어나기 어려운 경우 휨 압축응력 적용

▪ 항복 응력 (MPa)

(10도.설.해 3.2.5)

강 종		SS 400 SM 400 SMA400	SM 490	SM490Y SM 520 SMA490	SM 570 SMA570	HSB500	HSB600	HSB800
응력 종류, 판두께 (mm)								
기준 항복점	40 이하	235	315	355	450	380	450	690
	40 초과 75 이하	215	295 (315)	335 (355)	430 (450)			
	75 초과 100이하			325 (355)	420 (450)			

※ TMC 강재일 경우에는 ()안의 값을 적용하고, HSB 600인 경우에는 []안의 값을 적용한다.

강종 판두께 (mm)	SS 400 SM 400 SMA400	SM 490 [SM490C-TMC]	SM490Y SM 520 SMA490 [SM520C-TMC]	SM 570 SMA570 [SM570-TMC]
40 이하	$140 : \frac{l}{r} \leq 18.6$ $140 - 0.82 \left(\frac{l}{r} - 18.6 \right) :$ $18.6 < \frac{l}{r} \leq 92.8$ $\frac{1,200,000}{6,700 + \left(\frac{l}{r} \right)^2} : 92.8 < \frac{l}{r}$	$190 : \frac{l}{r} \leq 16.0$ $190 - 1.29 \left(\frac{l}{r} - 16.0 \right) :$ $16.0 < \frac{l}{r} \leq 80.1$ $\frac{1,200,000}{5,000 + \left(\frac{l}{r} \right)^2} : 80.1 < \frac{l}{r}$	$215 : \frac{l}{r} \leq 15.1$ $215 - 1.55 \left(\frac{l}{r} - 15.1 \right) :$ $15.1 < \frac{l}{r} \leq 75.5$ $\frac{1,200,000}{4,400 + \left(\frac{l}{r} \right)^2} : 75.5 < \frac{l}{r}$	$270 : \frac{l}{r} \leq 13.4$ $270 - 2.19 \left(\frac{l}{r} - 13.4 \right) :$ $13.4 < \frac{l}{r} \leq 67.1$ $\frac{1,200,000}{3,500 + \left(\frac{l}{r} \right)^2} : 67.1 < \frac{l}{r}$
40 초과 75 이하	$130 : \frac{l}{r} \leq 19.4$ $130 - 0.73 \left(\frac{l}{r} - 19.4 \right) :$ $19.4 < \frac{l}{r} \leq 97$ $\frac{1,200,000}{7,300 + \left(\frac{l}{r} \right)^2} : 97 < \frac{l}{r}$	$175 : \frac{l}{r} \leq 16.6$ $175 - 1.15 \left(\frac{l}{r} - 16.6 \right) :$ $16.6 < \frac{l}{r} \leq 82.8$ $\frac{1,200,000}{5,300 + \left(\frac{l}{r} \right)^2} : 82.8 < \frac{l}{r}$	$200 : \frac{l}{r} \leq 15.5$ $200 - 1.4 \left(\frac{l}{r} - 15.5 \right) :$ $15.5 < \frac{l}{r} \leq 77.7$ $\frac{1,200,000}{4,700 + \left(\frac{l}{r} \right)^2} : 77.7 < \frac{l}{r}$	$260 : \frac{l}{r} \leq 13.7$ $260 - 2.07 \left(\frac{l}{r} - 13.7 \right) :$ $13.7 < \frac{l}{r} \leq 68.6$ $\frac{1,200,000}{3,600 + \left(\frac{l}{r} \right)^2} : 68.6 < \frac{l}{r}$
75 초과 100 이하	$195 : \frac{l}{r} \leq 15.8$ $195 - 1.35 \left(\frac{l}{r} - 15.8 \right) :$ $15.8 < \frac{l}{r} \leq 78.9$ $\frac{1,200,000}{4,800 + \left(\frac{l}{r} \right)^2} : 78.9 < \frac{l}{r}$	$250 : \frac{l}{r} \leq 13.9$ $250 - 1.96 \left(\frac{l}{r} - 13.9 \right) :$ $13.9 < \frac{l}{r} \leq 69.4$ $\frac{1,200,000}{3,700 + \left(\frac{l}{r} \right)^2} : 69.4 < \frac{l}{r}$		
비고	l : 부재의 유효 좌굴길이 (mm) r : 부재 총단면의 단면 회전 반경 (mm)			

※ TMC 강재일 경우에는 일반강재에 40이하 값을 사용함

강종 판두께 (mm)	HSB500	HSB600	HSB800	비 고
80 이하	$230 : \frac{l}{r} \leq 14.6$ $230 - 1.72 \left(\frac{l}{r} - 14.6 \right) :$ $14.6 < \frac{l}{r} \leq 73.0$ $\frac{1,200,000}{4,100 + \left(\frac{l}{r} \right)^2} : 73.0 < \frac{l}{r}$	$270 : \frac{l}{r} \leq 13.4$ $270 - 2.19 \left(\frac{l}{r} - 13.4 \right) :$ $13.4 < \frac{l}{r} \leq 67.1$ $\frac{1,200,000}{3,500 + \left(\frac{l}{r} \right)^2} : 67.1 < \frac{l}{r}$	$380 : \frac{l}{r} \leq 18.0$ $380 - 4.18 \left(\frac{l}{r} - 18.0 \right) :$ $18.0 < \frac{l}{r} \leq 54.2$ $\frac{1,200,000}{2,300 + \left(\frac{l}{r} \right)^2} : 54.2 < \frac{l}{r}$	
80 초과 100 이하				
비고	l : 부재의 유효 좌굴길이 (mm) r : 부재 총단면의 단면 회전 반경 (mm)			

강 종		SS 400 SM 400 SMA400	SM 490 [SM490C-TMC]	SM490Y SM 520 SMA490 [SM520C-TMC]	SM 570 SMA570 SM570C-TMC]
판두께 (mm)					
$\frac{A_w}{A_c} \leq 2$	40 이하	$140 : \frac{l}{b} \leq 4.6$ $140 - 2.49(\frac{l}{b} - 4.6) :$ $4.6 < \frac{l}{b} \leq 30$	$190 : \frac{l}{b} \leq 4.0$ $190 - 3.91(\frac{l}{b} - 4.0) :$ $4.0 < \frac{l}{b} \leq 30$	$215 : \frac{l}{b} \leq 3.8$ $215 - 4.69(\frac{l}{b} - 3.8) :$ $3.8 < \frac{l}{b} \leq 27$	$270 : \frac{l}{b} \leq 3.4$ $270 - 6.64(\frac{l}{b} - 3.4) :$ $3.4 < \frac{l}{b} \leq 25$
	40 초과 75 이하	$130 : \frac{l}{b} \leq 4.9$	$175 : \frac{l}{b} \leq 4.1$	$200 : \frac{l}{b} \leq 3.9$ $200 - 4.24(\frac{l}{b} - 3.9) :$ $3.9 < \frac{l}{b} \leq 27$	$260 : \frac{l}{b} \leq 3.4$ $260 - 6.25(\frac{l}{b} - 3.4) :$ $3.4 < \frac{l}{b} \leq 25$
	75 초과 100 이하	$130 - 2.21(\frac{l}{b} - 4.9) :$ $4.9 < \frac{l}{b} \leq 30$	$175 - 3.48(\frac{l}{b} - 4.1) :$ $4.1 < \frac{l}{b} \leq 30$	$195 : \frac{l}{b} \leq 3.9$ $195 - 4.07(\frac{l}{b} - 3.9) :$ $3.9 < \frac{l}{b} \leq 27$	$250 : \frac{l}{b} \leq 3.5$ $250 - 5.94(\frac{l}{b} - 3.5) :$ $3.5 < \frac{l}{b} \leq 25$
$\frac{A_w}{A_c} > 2$	40 이하	$140 : \frac{l}{b} \leq \frac{9.3}{K}$ $140 - 1.24(K\frac{l}{b} - 9.3) :$ $\frac{9.3}{K} < \frac{l}{b} \leq 30$	$190 : \frac{l}{b} \leq \frac{8.0}{K}$ $190 - 1.95(K\frac{l}{b} - 8.0) :$ $\frac{8.0}{K} < \frac{l}{b} \leq 30$	$215 : \frac{l}{b} \leq \frac{7.5}{K}$ $215 - 2.35(K\frac{l}{b} - 7.5) :$ $\frac{7.5}{K} < \frac{l}{b} \leq 27$	$270 : \frac{l}{b} \leq \frac{6.7}{K}$ $270 - 3.32(K\frac{l}{b} - 6.7) :$ $\frac{6.7}{K} < \frac{l}{b} \leq 25$
	40 초과 75 이하	$130 : \frac{l}{b} \leq \frac{9.7}{K}$	$175 : \frac{l}{b} \leq \frac{8.3}{K}$	$200 : \frac{l}{b} \leq \frac{7.8}{K}$ $200 - 2.12(K\frac{l}{b} - 7.8) :$ $\frac{7.8}{K} < \frac{l}{b} \leq 27$	$260 : \frac{l}{b} \leq \frac{6.9}{K}$ $260 - 3.12(K\frac{l}{b} - 6.9) :$ $\frac{6.9}{K} < \frac{l}{b} \leq 25$
	75 초과 100 이하	$130 - 1.10(K\frac{l}{b} - 9.7) :$ $\frac{9.7}{K} < \frac{l}{b} \leq 30$	$175 - 1.74(K\frac{l}{b} - 8.3) :$ $\frac{8.3}{K} < \frac{l}{b} \leq 30$	$195 : \frac{l}{b} \leq \frac{7.9}{K}$ $195 - 2.04(K\frac{l}{b} - 7.9) :$ $\frac{7.9}{K} < \frac{l}{b} \leq 27$	$250 : \frac{l}{b} \leq \frac{6.9}{K}$ $250 - 2.97(K\frac{l}{b} - 6.9) :$ $\frac{6.9}{K} < \frac{l}{b} \leq 25$
비 고		A_w : 복부판의 총 단면적 (mm^2) A_c : 압축플랜지의 총단면적 (mm^2) l : 압축플랜지의 고정점간의 거리 (mm) b : 압축플랜지의 폭 (mm) $K : \sqrt{3 + \frac{A_w}{2A_c}}$			

※ TMC 강재일 경우에는 ()안의 값을 적용한다.

강 종		HSB500	HSB600	HSB800	비 고
판두께 (mm)					
$\frac{A_w}{A_c} \leq 2$	100 이하	$230 : \frac{l}{b} \leq 3.6$ $230 - 5.19(\frac{l}{b} - 3.6) :$ $3.6 < \frac{l}{b} \leq 27$	$270 : \frac{l}{b} \leq 3.4$ $270 - 6.64(\frac{l}{b} - 3.4) :$ $3.4 < \frac{l}{b} \leq 25$	$380 : \frac{l}{b} \leq 5.4$ $380 - 12.63(\frac{l}{b} - 5.4) :$ $5.4 < \frac{l}{b} \leq 19$	
$\frac{A_w}{A_c} > 2$	100 이하	$230 : \frac{l}{b} \leq \frac{7.3}{K}$ $230 - 2.60(K\frac{l}{b} - 7.3) :$ $\frac{7.3}{K} < \frac{l}{b} \leq 27$	$270 : \frac{l}{b} \leq \frac{6.7}{K}$ $270 - 3.32(K\frac{l}{b} - 6.7) :$ $\frac{6.7}{K} < \frac{l}{b} \leq 25$	$380 : \frac{l}{b} \leq \frac{10.8}{K}$ $380 - 6.13(K\frac{l}{b} - 10.8) :$ $\frac{10.8}{K} < \frac{l}{b} \leq 19$	
비 고		A_w : 복부판의 총 단면적 (mm^2) A_c : 압축플랜지의 총단면적 (mm^2) l : 압축플랜지의 고정점간의 거리 (mm) b : 압축플랜지의 폭 (mm) $K : \sqrt{3 + \frac{A_w}{2A_c}}$			

▪ 강재 주거더의 허용응력 증가율

(10 도.설.해 3.9.3.1)

하중의 조합			증 가 율 (%)	
			정의 휨모멘트를 받는 부분	부의 휨모멘트를 받는 부분
1	크리프의 영향과 건조수축의 영향을 제외한 주하중		0	0
2	주 하 중	압 축 연	15	0
		인 장 연	0	0
3	주하중 + 바닥판 콘크리트와 강재 주거더와의 온도차	압 축 연	30	15
		인 장 연	15	15
4	가설시 하중	압 축 연	25	25
		인 장 연	25	25

▪ 마찰 이음용 고장력 볼트 허용력 (kN) (1볼트 1마찰면 마다)

(10 도.설.해 3.3.2.3)

볼트의 등급	F 8 T	F 10 T	S 10 T	F 13 T	S 13 T
나사호칭					
M 20	31	39	39	50	50
M 22	39	48	48	63	63
M 24	45	56	56	73	73
M 27	58	73	73	-	-
M 30	71	89	89	-	-

② 바닥판 콘크리트 (도.설.해 3.9.2.7, 도.설.해 3.9.2.8, 도.설.해 4.2.3, 도.설.해 4.6.3.3)

콘크리트 설계 기준강도 (f_{ck})	27.0	MPa
콘크리트 탄성계수 (E_c)	26,702	MPa
전단 탄성계수 (G_c)	11,444	MPa
탄성계수비 (n)	7	
바닥판 콘크리트와 강재 주거더와의 온도차	10	℃
바닥판 콘크리트와 강재의 선팽창계수 (α)	0.000012	
건조수축 계수 (ϵ_s)	0.000270	
CREEP 계수 (ϕ_2)	$\phi_2 = 2\phi_1$: 4	

③ 바닥판 철근

철근 설계 항복강도 (f_y)	400	MPa
철근 탄성계수 (E_s)	200,000	MPa
허용압축응력 (f_{ca})	180	MPa
허용인장응력 (f_{ta})	160	MPa

2) 하 중 조 건

(1) 고 정 하 중

(도.설.해 2.1.2)

- ① 철근 콘크리트 : 25.000 kN/m³
- ② 무근 콘크리트 : 23.500 kN/m³
- ③ 강 재 : 78.500 kN/m³
- ④ 포장 콘크리트 : 23.000 kN/m³

(2) 활 하 중

(도.설.해 2.1.3)

① 설계 차선수 산정

$$W_c = 11.385 \text{ m}, N = 3 \text{ 차로}$$

$$W = 11.385 / 3 = 3.795 \text{ m} > 3.600 \text{ m}$$

∴ 설계 차로폭 3.600m마다 3차로 연속으로 재하

② 1등급 교량으로서 DB-24 및 DL-24 하중을 적용한다.

▪ DB-24 하중

- 전륜하중 : $P_f = 24.000$ kN

- 후륜하중 : $P_r = 96.000$ kN

▪ DL-24 하중

- 차로당 등분포 하중 : $W_l = 12.700$ kN/m

- 모멘트 계산시 집중하중 : $P_m = 108.000$ kN

③ 총 격 계 수

$$i = 15 / (40 + L) = 0.158 < 0.300 \therefore i = 0.158$$

(3) 콘크리트의 Creep와 건조수축의 영향

- 철근 콘크리트의 바닥판의 Creep와 건조수축의 영향에 대한 단면력을 검토한다.

(4) 지점침하에 의한 영향

- 각 지점에서 발생할 수 있는 부등침하의 발생을 가정하여 가장 불리한 단면력을 산정한다.

(5) 온도변화에 대한 영향

- 바닥판과 주형의 온도차 발생시 생기는 단면력 및 응력을 산정하고 이때의 온도 변화는 직선변화 한다고 가정한다.

3) 설 계 방 법

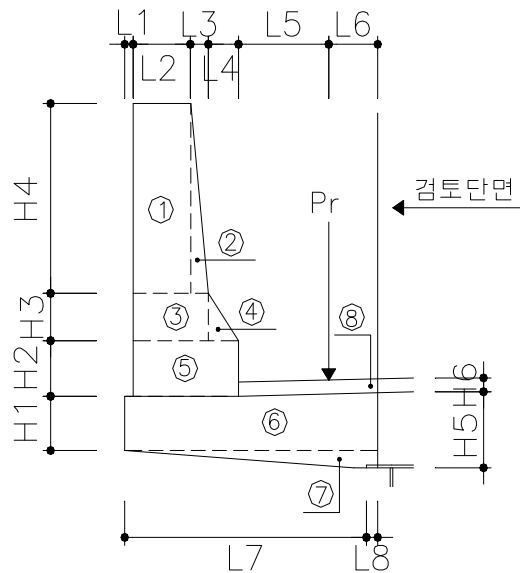
- (1) 바 닥 판 : 강도설계법
- (2) Steel Box Girder : 허용응력 설계법

4) 참 고 문 헌

- (1) 도로교 설계기준 (2010)
- (2) 도로교 설계기준 해설 (2008)
- (3) 콘크리트 구조 설계기준 (2007)
- (4) 도로설계 편람 (2008)
- (5) 도로설계 요령 (2001)
- (6) 강구조 편람 (1995)
- (7) 강도로교 상세부 설계지침 (2006)

1. 바닥판설계

1-1. 좌측 캔틸레버부



콘크리트 단위중량	: 25.000 kN/m ³	H1 =	0.250 m	L1 =	0.030 m
포장 단위중량	: 23.000 kN/m ³	H2 =	0.125 m	L2 =	0.230 m
설계 속도	: 120.000 km/h	H3 =	0.175 m	L3 =	0.070 m
트럭의 1후륜하중 (Pr)	: 96.000 kN	H4 =	0.700 m	L4 =	0.120 m
곡선 반경(R)	: ∞ m	H5 =	0.300 m	L5 =	0.300 m
		H6 =	0.080 m	L6 =	0.120 m
				L7 =	0.820 m
				L8 =	0.050 m
				L9 =	0.000 m

가) 고정하중

NO.	작 용 하 중 (kN)	거리 (m)	모멘트(kN · m)
1	$0.23 \times 0.7 \times 25 = 4.025$	0.725	2.918
2	$\frac{1}{2} \times 0.07 \times 0.7 \times 25 = 0.613$	0.587	0.359
3	$0.30 \times 0.175 \times 25 = 1.313$	0.690	0.906
4	$\frac{1}{2} \times 0.12 \times 0.175 \times 25 = 0.263$	0.500	0.131
5	$0.42 \times 0.125 \times 25 = 1.313$	0.630	0.827
6	$0.870 \times 0.25 \times 25 = 5.438$	0.435	2.365
7	$\frac{1}{2} \times 0.870 \times 0.05 \times 25 = 0.544$	0.290	0.158
8	$0.08 \times 0.420 \times 23 = 0.773$	0.210	0.162
TOTAL	14.279		7.826

$$\therefore M_d = 7.826 \text{ kN} \cdot \text{m}$$

나) 활하중 (DB-24 : $P_r = 96 \text{ kN}$)

윤하중 분포폭

(도.설 3.6.1.4)

$$E = 0.8 \cdot X + 1.14 = 0.8 \times 0.12 + 1.14 = 1.236 \text{ m} \quad \text{여기서, } X = 0.120 \text{ m}$$

충격계수

(도.설 2.1.4)

$$i = 15 / (40 + L) = 15 / (40 + 0.12) = 0.374 > 0.3 \quad \therefore i = 0.3$$

$$Ml+i = P_r/E \cdot X \cdot (1 + i) = (96 / 1.236) \times 0.12 \times (1 + 0.3) = 12.117 \text{ kN} \cdot \text{m/m}$$

다) 차량 충돌 하중 (도.설.해 2.4.3.5)

수평충돌력 H는 노면상 1.0m 높이에 교축을 따라 1.0m마다 작용시

$$H = (V/60)^2 \times 7.5 + 2.5 = (120/60)^2 \times 7.5 + 2.5 = 32.500 \text{ kN/m} \quad h = 1.000 \text{ m}$$

$$M_{co} = 32.500 \times 1.000 = 32.500 \text{ kN} \cdot \text{m/m}$$

라) 풍하중

$$P_w = 3.0 \text{ kN/m}^2 \times 1.320 \text{ m} = 3.960 \text{ kN/m}$$

$$M_w = 3.960 \text{ kN/m} \times 0.890 \text{ m} = 3.524 \text{ kN} \cdot \text{m/m}$$

마) 하중 조합

(도.설 2.2.3.2)

계수 모멘트

$$\begin{aligned} \textcircled{1} \quad Mu_1 &= 1.3 M_d + 2.15 Ml+i \\ &= 1.3 \times 7.826 + 2.15 \times 12.117 = 36.226 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{2} \quad Mu_2 &= 1.3 M_d + 1.3 Ml+i + 1.3 M_{co} \\ &= 1.3 \times 7.826 + 1.3 \times 12.117 + 1.3 \times 32.5 = 68.177 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{3} \quad Mu_3 &= 1.3 M_d + 1.3 Ml+i + 0.65 M_w \\ &= 1.3 \times 7.826 + 1.3 \times 12.117 + 0.65 \times 3.524 = 28.217 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{4} \quad Mu_4 &= 1.2 M_d + 1.2 M_w + 1.2 M_{co} \\ &= 1.2 \times 7.826 + 1.2 \times 3.524 + 1.2 \times 32.5 = 52.621 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{5} \quad Mu_5 &= 1.3 M_d + 1.3 M_w \\ &= 1.3 \times 7.826 + 1.3 \times 3.524 = 14.756 \text{ kN} \cdot \text{m/m} \end{aligned}$$

사용 모멘트

$$\begin{aligned} M &= 1.0 M_d + 1.0 Ml+i + 0.3 M_w \\ &= 1.0 \times 7.826 + 1.0 \times 12.117 + 0.3 \times 3.524 = 21.001 \text{ kN} \cdot \text{m/m} \end{aligned}$$

바) 바닥판의 최소 두께 ($X \leq 0.25$ 인 경우)

(㉠ 도.설 3.6.1.5)

$$h_{min} = (280 \cdot L + 180) = \{(280 \times 0.12) + 180\} = 214 \text{ mm}$$

$$h_{use} = 300.0 \text{ mm} > 214.0 \text{ mm} \quad \mathbf{O.K!!}$$

사) 단면검토

◀ 철근량 산정

① 캔틸레버부

[DESIGN CONDITION]

$$f_{ck} = 27 \text{ MPa} \quad f_y = 400 \text{ MPa}$$

$$M_u = 68.177 \text{ kN} \cdot \text{m}$$

$$b = 1000 \text{ mm} \quad h = 300.0 \text{ mm}$$

$$d' = 50 \text{ mm} \quad d = 250.0 \text{ mm}$$

$$\phi(\text{Bending}) = 0.85 \quad \beta_1 = 0.85$$

[Req'd d & As]

(㉠ 콘.설 6.3.2)

$$a = A_s \times f_y / (0.85 \times f_{ck} \times b) = 0.0174 A_s = 27.692 \text{ mm}$$

$$M_u = \phi \times A_s \times f_y \times (d - a/2) = -3.0 A_s^2 + 85000 A_s = 68177000$$

$$\epsilon_t = 0.003 \times (H - a/\beta_1 - D_{c_min}) / (a/\beta_1) = 0.02002 > 0.004$$

O.K.!!

$$0.005 < \epsilon_t \quad \phi_f = 0.850$$

$$\therefore \text{Req'd } A_s = 825.9 \text{ mm}^2$$

$$\text{Min. } A_s = \text{Req'd } A_s \times 4/3 = 1101.1 \text{ mm}^2$$

$$\text{Min. } A_s = 0.002 \times b \times d = 500.0 \text{ mm}^2$$

$$\text{Min. } A_s = 1.4/f_y \times b \times d = 875.0 \text{ mm}^2$$

$$\text{Min. } A_s = 0.25 \sqrt{f_{ck}} / f_y \times b \times d = 811.9 \text{ mm}^2$$

$$\text{USE } H 16 @ 125 = 1588.8 \text{ mm}^2$$

$$A_{suse} = 1588.8 \text{ mm}^2$$

O.K. !!

[RE-BAR RATIO CHECK]

$$P = A_s / (b \times d) = 0.00636 < P_{max} = 0.75 \times p_b = 0.0219 \quad \mathbf{O.K.!!}$$

[DESIGN MOMENT CHECK]

$$\text{Max. } c = 0.75 \times 600 / (600 + f_y) \times d = 112.500 \text{ mm} > c = a/0.85 = 32.578 \text{ mm}$$

$$\text{Max. } a = 0.85 \times c = 95.625 \text{ mm} > a = f_y \times A_s / (0.85 \times f_{ck} \times b) = 27.692 \text{ mm}$$

$$j_d = d - a/2 = 236.154 \text{ mm}$$

$$C = 0.85 \times f_{ck} \times a \times b = 635.520 \text{ kN} \quad T = f_y \times A_s = 635.520 \text{ kN}$$

$$\phi M_n = \phi f_y \times A_s \times j_d = 127.569 \text{ kN} \cdot \text{m} > M_u = 68.177 \text{ kN} \cdot \text{m} \quad \mathbf{O.K.}$$

아) 사용성(균열) 검토

$$M_{\max} = 21.001 \text{ kN} \cdot \text{m/m}$$

$$\text{탄성계수비}(n) = 7$$

$$\text{철근비}(p) = A_s / b d = 1588.8 / 1000 \times 250 = 0.0064$$

$$\text{중립축}(k) = -np + \sqrt{\{(np)^2 + 2np\}} = -0.0448 + \sqrt{\{(0.0448)^2 + 2 \times 0.0448\}} = 0.258$$

$$\text{중립축 거리}(x) = k \times d = 0.258 \times 250 = 64.500 \text{ mm}$$

$$j = 1 - (k / 3) = 1 - (0.258 / 3) = 0.914$$

$$\begin{aligned} f_{s\max} &= \frac{M_{\max}}{p b j d^2} = \frac{21.001 \times 1000000}{0.0064 \times 1000 \times 0.914 \times 250.0^2} \\ &= 57.443 \text{ MPa} < 0.6 f_y = 240.000 \text{ MPa} \quad \mathbf{O.K!!} \end{aligned}$$

$$\text{최소두께}(C_c) = d' - \text{철근직경} / 2 = 50 - 16 / 2 = 42.00 \text{ mm}$$

$$\text{인장연단폭}(S_1) = 375 (210 / f_s) - 2.5 C_c = 375 (210 / 57.443) - 2.5 \times 42 = 1269.674 \text{ mm}$$

$$\text{인장연단폭}(S_2) = 300 (210 / f_s) = 300 (210 / 57.443) = 1096.739 \text{ mm}$$

$$\text{철근 소요중심간격}(S_a) = \text{Min} (S_1, S_2) = 1096.739 \text{ mm}$$

$$\text{철근 평균간격 } S = 125.0 \text{ mm} \leq 1096.739 \text{ mm} \quad \mathbf{O.K!!}$$

1-2. 중앙부

가) 고정하중

$$\begin{aligned}
 \text{철근콘크리트 : } & 0.300 \text{ m} \times 25.000 \text{ kN/m}^3 = 7.500 \text{ kN/m}^2 \\
 \text{포장 : } & 0.080 \text{ m} \times 23.000 \text{ kN/m}^3 = 1.840 \text{ kN/m}^2 \\
 \hline
 & W_d = 9.340 \text{ kN/m}^2 \\
 \text{계산지간 } L = & 2.550 \text{ m} \quad \text{바닥판 지점의 수 } n = 5 \\
 M_d = (1/10) \cdot W_d \cdot L^2 = & (1/10) \times 9.34 \times 2.55^2 = 6.073 \text{ kN} \cdot \text{m}
 \end{aligned}$$

나) 활하중 (DB-24 : $P_r = 96.0 \text{ kN}$)

충격계수 (도.설 2.1.4)

$$i = 15 / (40 + L) = 15 / (40 + 2.55) = 0.353 > 0.3 \quad \therefore i = 0.3$$

$$\begin{aligned}
 M_{l+i} &= ((L+0.6) / 9.6) \cdot P_r \cdot (1+i) = ((2.55 + 0.6) / 9.6) \times 96 \times (1 + 0.3) \\
 &= 40.950 \text{ kN} \cdot \text{m}
 \end{aligned}$$

연속바닥판이므로, (도.설 3.6.1.4)

$$M_{l+i} = 0.8 \times 40.95 = 32.760 \text{ kN} \cdot \text{m/m}$$

다) 하중 조합 (도.설 2.2.3.2)

① 계수 모멘트

$$\begin{aligned}
 M_{u1} &= 1.3 M_d + 2.15 M_{l+i} \\
 &= 1.3 \times 6.073 + 2.15 \times 32.76 = 78.329 \text{ kN} \cdot \text{m/m}
 \end{aligned}$$

① 사용 모멘트

$$\begin{aligned}
 M &= 1.0 M_d + 1.0 M_{l+i} \\
 &= 1.0 \times 6.073 + 1.0 \times 32.76 = 38.833 \text{ kN} \cdot \text{m/m}
 \end{aligned}$$

라) 바닥판의 최소 두께 (도.설 3.6.1.5)

$$h_{min} = (30 \cdot L + 130) = \{(30 \times 2.55) + 130\} = 207 \text{ mm}$$

$$h_{use} = 300.0 \text{ mm} > 207.0 \text{ mm} \quad \mathbf{O.K!!}$$

마) 단면검토

◀ 철근량 산정

① 캔틸레버부

[DESIGN CONDITION]

$$f_{ck} = 27 \text{ MPa} \quad f_y = 400 \text{ MPa}$$

$$M_u = 78.329 \text{ kN} \cdot \text{m}$$

$$b = 1000 \text{ mm} \quad h = 300 \text{ mm}$$

$$d' = 50 \text{ mm} \quad d = 250 \text{ mm}$$

$$\emptyset(\text{Bending}) = 0.85 \quad \beta_1 = 0.85$$

[Req'd d & As]

(콘.설 6.3.2)

$$a = A_s \times f_y / (0.85 \times f_{ck} \times b) = 0.0174 A_s = 27.692 \text{ mm}$$

$$M_u = \Phi \times A_s \times f_y \times (d - a/2) = -3.0 A_s^2 + 85000 A_s$$

$$= 78329000$$

$$\epsilon_t = 0.003 \times (H - a/\beta_1 - D_{c_min}) / (a/\beta_1) = 0.02002 > 0.004$$

0.K.!!

$$0.005 < \epsilon_t \quad \phi_f = 0.850$$

$$\therefore \text{Req'd } A_s = 953.2 \text{ mm}^2$$

$$\text{Min. } A_s = \text{Req'd } A_s \times 4/3 = 1270.9 \text{ mm}^2$$

$$\text{Min. } A_s = 0.002 \times b \times d = 500.0 \text{ mm}^2$$

$$\text{Min. } A_s = 1.4/f_y \times \frac{b \times d}{4} = 875.0 \text{ mm}^2$$

$$\text{Min. } A_s = 0.25 \sqrt{f_{ck}} / f_y \times b \times d = 811.9 \text{ mm}^2$$

$$\text{USE } H 16 @ 125 = 1588.8 \text{ mm}^2$$

$$A_{s\text{use}} = 1588.8 \text{ mm}^2$$

0.K. !!

[RE-BAR RATIO CHECK]

$$P = A_s / (b \times d) = 0.0064 < P_{max} = 0.75 \times p_b = 0.0219 \quad \mathbf{0.K.!!}$$

[DESIGN MOMENT CHECK]

$$\text{Max. } c = 0.75 \times 600 / (600 + f_y) \times d = 112.500 \text{ mm} > c = a/0.85 = 32.578 \text{ mm}$$

$$\text{Max. } a = 0.85 \times c = 95.625 \text{ mm} > a = f_y \times A_s / (0.85 \times f_{ck} \times b) = 27.692 \text{ mm}$$

$$jd = d - a/2 = 236.154 \text{ mm}$$

$$C = 0.85 \times f_{ck} \times a \times b = 635.520 \text{ kN} \quad T = f_y \times A_s = 635.520 \text{ kN}$$

$$\Phi M_n = \Phi f_y \times A_s \times jd = 127.569 \text{ kN} \cdot \text{m} > M_u = 78.329 \text{ kN} \cdot \text{m} \quad \mathbf{0.K.}$$

아) 사용성(균열) 검토

$$M_{\max} = 38.833 \text{ kN} \cdot \text{m/m}$$

$$\text{탄성계수비}(n) = E_s / E_c = 7$$

$$\text{철근비}(p) = A_s / b d = 1588.8 / 1000 \times 250 = 0.0064$$

$$\text{중립축}(k) = -np + \sqrt{\{(np)^2 + 2np\}} = -0.0448 + \sqrt{\{(0.0448)^2 + 2 \times 0.0448\}} = 0.258$$

$$\text{중립축 거리}(x) = k \times d = 0.258 \times 250 = 64.500 \text{ mm}$$

$$j = 1 - (k / 3) = 1 - (0.258) / 3 = 0.914$$

$$\begin{aligned} f_{s\max} &= \frac{M_{\max}}{pbjd^2} = \frac{38.833 \times 1000000}{0.0064 \times 1000 \times 0.914 \times 250^2} \\ &= 106.217 \text{ MPa} < 0.6 f_y = 240.000 \text{ MPa} \quad \mathbf{0.K!!} \end{aligned}$$

$$\text{최소두께}(C_c) = d' - \text{철근직경} / 2 = 50 - 16 / 2 = 42.00 \text{ mm}$$

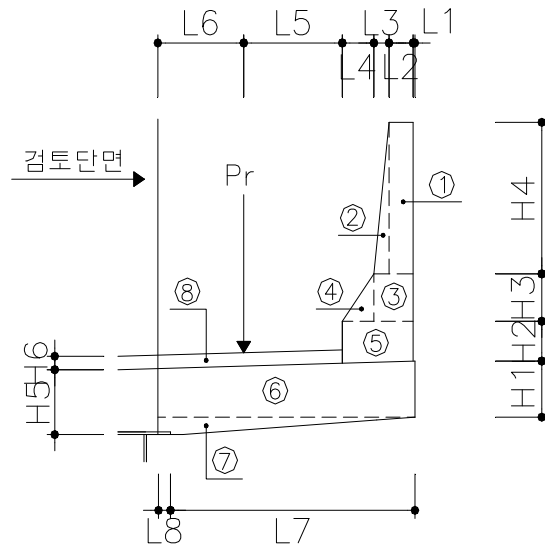
$$\text{인장연단폭}(S_1) = 375 (210 / f_s) - 2.5C_c = 375 (210 / 106.217) - 2.5 \times 42 = 640.157 \text{ mm}$$

$$\text{인장연단폭}(S_2) = 300 (210 / f_s) = 300 (210 / 106.217) = 593.125 \text{ mm}$$

$$\text{철근 소요중심간격}(S_a) = \text{Min} (S_1, S_2) = 593.125 \text{ mm}$$

$$\text{철근 평균간격 } S = 125.0 \text{ mm} \leq 593.125 \text{ mm} \quad \mathbf{0.K!!}$$

1-3. 우측 캔틸레버부



콘크리트 단위중량	: 25.000 kN/m ³	H1 =	0.250 m	L1 =	0.005 m
포장 단위중량	: 23.000 kN/m ³	H2 =	0.075 m	L2 =	0.095 m
설계 속도	: 120.000 km/h	H3 =	0.175 m	L3 =	0.060 m
트럭의 1후륜하중 (Pr)	: 96.000 kN	H4 =	0.560 m	L4 =	0.125 m
곡선 반경(R)	: ∞ m	H5 =	0.300 m	L5 =	0.300 m
		H6 =	0.080 m	L6 =	0.295 m
				L7 =	0.830 m
				L8 =	0.050 m
				L9 =	0.000 m

가) 고정하중

NO.	작 용 하 중 (kN)	거리 (m)	모멘트(kN · m)
1	$0.095 \times 0.56 \times 25 = 1.330$	0.828	1.101
2	$\frac{1}{2} \times 0.06 \times 0.56 \times 25 = 0.420$	0.760	0.319
3	$0.155 \times 0.175 \times 25 = 0.678$	0.798	0.541
4	$\frac{1}{2} \times 0.125 \times 0.175 \times 25 = 0.273$	0.678	0.185
5	$0.28 \times 0.075 \times 25 = 0.525$	0.735	0.386
6	$1.025 \times 0.25 \times 25 = 5.500$	0.440	2.420
7	$\frac{1}{2} \times 0.880 \times 0.100 \times 25 = 0.550$	0.293	0.161
8	$0.08 \times 0.595 \times 23 = 1.095$	0.298	0.326
TOTAL	10.371		5.439

$$\therefore Md = 5.439 \text{ kN} \cdot \text{m}$$

나) 활하중 (DB-24 : $Pr = 96 \text{ kN}$)

윤하중 분포폭 (도.설 3.6.1.4)

$$E = 0.8 \cdot X + 1.14 = 0.8 \times 0.295 + 1.14 = 1.376 \text{ m} \quad \text{여기서, } X = 0.295 \text{ m}$$

충격계수 (도.설 2.1.4)

$$i = 15 / (40 + L) = 15 / (40 + 0.295) = 0.372 > 0.3 \quad \therefore i = 0.3$$

$$MI+i = Pr/E \cdot X \cdot (1 + i) = (96 / 1.376) \times 0.295 \times (1 + 0.3) = 26.756 \text{ kN} \cdot \text{m/m}$$

다) 차량 충돌 하중 (도.설.해 2.4.3.5)

수평충돌력 H 는 노면상 1.0m 높이에 교축을 따라 1.0m마다 작용시

$$H = (V/60)^2 \times 7.5 + 2.5 = (120/60)^2 \times 7.5 + 2.5 = 32.500 \text{ kN/m} \quad h = 1.000 \text{ m}$$

$$Mco = 32.500 \times 1.000 = 32.500 \text{ kN} \cdot \text{m/m}$$

라) 풍하중

$$Pw = 3.0 \text{ kN/m}^2 \times 1.130 \text{ m} = 3.390 \text{ kN/m}$$

$$Mw = 3.390 \text{ kN/m} \times 0.795 \text{ m} = 2.695 \text{ kN} \cdot \text{m/m}$$

마) 하중 조합 (도.설 2.2.3.2)

계수 모멘트

$$\begin{aligned} \textcircled{1} \quad Mu1 &= 1.3 \text{ Md} + 2.15 \text{ MI}+i \\ &= 1.3 \times 5.439 + 2.15 \times 26.756 = 64.596 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{2} \quad Mu2 &= 1.3 \text{ Md} + 1.3 \text{ MI}+i + 1.3 \text{ Mco} \\ &= 1.3 \times 5.439 + 1.3 \times 26.756 + 1.3 \times 32.5 = 84.103 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{3} \quad Mu3 &= 1.3 \text{ Md} + 1.3 \text{ MI}+i + 0.65 \text{ Mw} \\ &= 1.3 \times 5.439 + 1.3 \times 26.756 + 0.65 \times 2.695 = 43.605 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{4} \quad Mu4 &= 1.2 \text{ Md} + 1.2 \text{ Mw} + 1.2 \text{ Mco} \\ &= 1.2 \times 5.439 + 1.2 \times 2.695 + 1.2 \times 32.5 = 48.761 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{5} \quad Mu5 &= 1.3 \text{ Md} + 1.3 \text{ Mw} \\ &= 1.3 \times 5.439 + 1.3 \times 2.695 = 10.574 \text{ kN} \cdot \text{m/m} \end{aligned}$$

사용 모멘트

$$\begin{aligned} M &= 1.0 \text{ Md} + 1.0 \text{ MI}+i + 0.3 \text{ Mw} \\ &= 1.0 \times 5.439 + 1.0 \times 26.756 + 0.3 \times 2.695 = 33.003 \text{ kN} \cdot \text{m/m} \end{aligned}$$

바) 바닥판의 최소 두께 ($X > 0.25$ 인 경우)

(도.설 3.6.1.5)

$$h_{min} = (80 \cdot L + 230) = \{(80 \times 0.295) + 230\} = 254 \text{ mm}$$

$$h_{use} = 300.0 \text{ mm} > 254.0 \text{ mm} \quad \mathbf{O.K!!}$$

사) 단면검토

◀ 철근량 산정

① 캔틸레버부

[DESIGN CONDITION]

$$f_{ck} = 27 \text{ MPa} \quad f_y = 400 \text{ MPa}$$

$$M_u = 84.103 \text{ kN} \cdot \text{m}$$

$$b = 1000 \text{ mm} \quad h = 300.0 \text{ mm}$$

$$d' = 50 \text{ mm} \quad d = 250.0 \text{ mm}$$

$$\phi(\text{Bending}) = 0.85 \quad \beta_1 = 0.85$$

[Req'd d & As]

(콘.설 6.3.2)

$$a = A_s \times f_y / (0.85 \times f_{ck} \times b) = 0.0174 A_s = 27.692 \text{ mm}$$

$$M_u = \phi \times A_s \times f_y \times (d - a/2) = -3.0 A_s^2 + 85000 A_s$$

$$= 84103000$$

$$\epsilon_t = 0.003 \times (H - a/\beta_1 - D_{c_min}) / (a/\beta_1) = 0.02002 > 0.004$$

O.K.!!

$$0.005 < \epsilon_t \quad \phi_f = 0.850$$

$$\therefore \text{Req'd } A_s = 1026.2 \text{ mm}^2$$

$$\text{Min. } A_s = \text{Req'd } A_s \times 4/3 = 1368.2 \text{ mm}^2$$

$$\text{Min. } A_s = 0.002 \times b \times d = 500.0 \text{ mm}^2$$

$$\text{Min. } A_s = 1.4/f_y \times b \times d = 875.0 \text{ mm}^2$$

$$\text{Min. } A_s = 0.25 \sqrt{f_{ck}} / f_y \times b \times d = 811.9 \text{ mm}^2$$

$$\text{USE H 16 @ 125} = 1588.8 \text{ mm}^2$$

$$A_{suse} = 1588.8 \text{ mm}^2$$

O.K. !!

[RE-BAR RATIO CHECK]

$$P = A_s / (b \times d) = 0.00636 < P_{max} = 0.75 \times p_b = 0.0219 \quad \mathbf{O.K.!!}$$

[DESIGN MOMENT CHECK]

$$\text{Max. } c = 0.75 \times 600 / (600 + f_y) \times d = 112.500 \text{ mm} > c = a/0.85 = 32.578 \text{ mm}$$

$$\text{Max. } a = 0.85 \times c = 95.625 \text{ mm} > a = f_y \times A_s / (0.85 \times f_{ck} \times b) = 27.692 \text{ mm}$$

$$j d = d - a/2 = 236.154 \text{ mm}$$

$$C = 0.85 \times f_{ck} \times a \times b = 635.520 \text{ kN} \quad T = f_y \times A_s = 635.520 \text{ kN}$$

$$\phi M_n = \phi f_y \times A_s \times j d = 127.569 \text{ kN} \cdot \text{m} > M_u = 84.103 \text{ kN} \cdot \text{m} \quad \mathbf{O.K.}$$

아) 사용성(균열) 검토

$$M_{\max} = 33.003 \text{ kN} \cdot \text{m/m}$$

$$\text{탄성계수비}(n) = 7$$

$$\text{철근비}(p) = A_s / b d = 1588.8 / 1000 \times 250 = 0.0064$$

$$\text{중립축}(k) = -np + \sqrt{\{(np)^2 + 2np\}} = -0.0448 + \sqrt{\{(0.0448)^2 + 2 \times 0.0448\}} = 0.258$$

$$\text{중립축 거리}(x) = k \times d = 0.258 \times 250 = 64.500 \text{ m}$$

$$j = 1 - (k / 3) = 1 - (0.258) / 3 = 0.914$$

$$\begin{aligned} f_{s\max} &= \frac{M_{\max}}{p b j d^2} = \frac{33.003 \times 1000000}{0.0064 \times 1000 \times 0.914 \times 250^2} \\ &= 90.271 \text{ MPa} < 0.6 f_y = 240.000 \text{ MPa} \quad \mathbf{O.K!!} \end{aligned}$$

$$\text{최소두께}(C_c) = d' - \text{철근직경} / 2 = 50 - 16 / 2 = 42.00 \text{ mm}$$

$$\text{인장연단폭}(S_1) = 375 (210 / f_s) - 2.5 C_c = 375 (210 / 90.271) - 2.5 \times 42 = 771.123 \text{ mm}$$

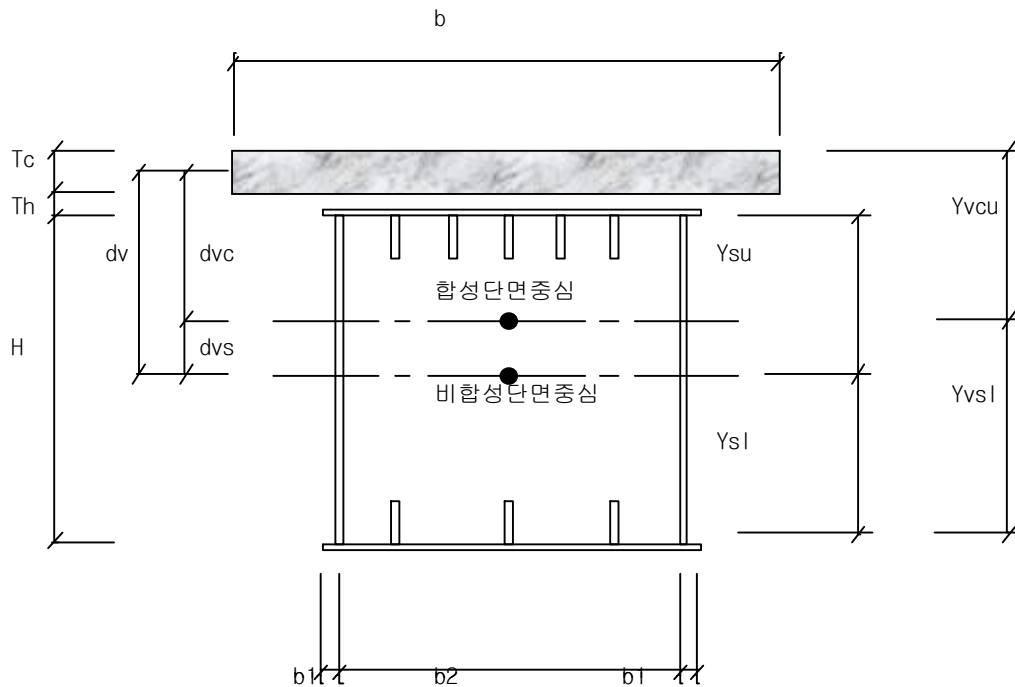
$$\text{인장연단폭}(S_2) = 300 (210 / f_s) = 300 (210 / 90.271) = 697.899 \text{ mm}$$

$$\text{철근 소요중심간격}(S_a) = \text{Min} (S_1, S_2) = 697.899 \text{ mm}$$

$$\text{철근 평균간격 } S = 125.0 \text{ mm} \leq 697.899 \text{ mm} \quad \mathbf{O.K!!}$$

2. 단면상수 산정

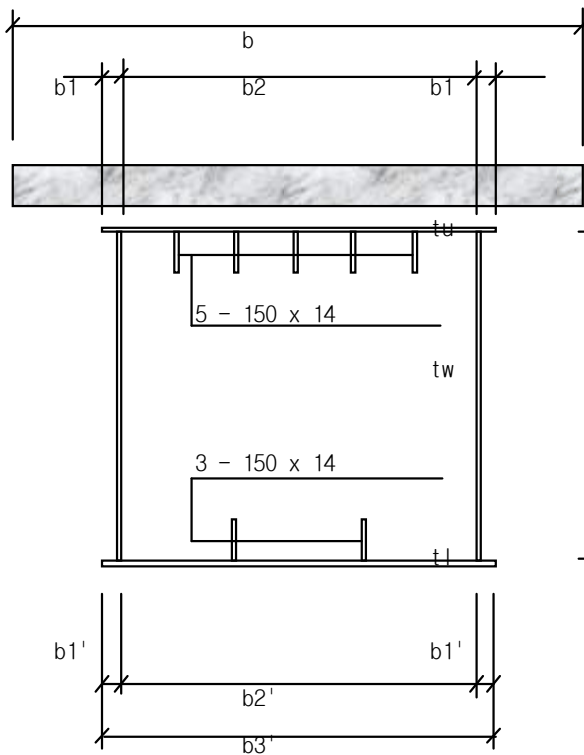
2-1. Steel Box 주형 단면상수 산정



주형의 탄성변형 및 부정정력을 계산하는 경우에는 정부모멘트에 관계없이 바닥판 콘크리트의 합성작용을 고려한다.

- b - 바닥판 콘크리트의 폭
- Tc - 바닥판 콘크리트의 두께
- Th - 바닥판 콘크리트의 현치 높이
- N - 강재와 콘크리트의 탄성계수비 ($N = E_s / E_c$)
- Ac - 바닥판 콘크리트의 단면적
- Av - 합성후 (강재+바닥판 콘크리트)의 환산단면적
- Ic - 바닥판 콘크리트의 단면2차모멘트
- dv - 강재단면 도심에서 바닥판 도심까지의 거리
- dvc - 합성단면 도심에서 바닥판 도심까지의 거리
- dvs - 합성단면 도심에서 강재단면 도심까지의 거리 (합성전 및 합성후단면에서의 도심축 이동량)
- I33 - 합성전 강재단면의 3축방향(중방향) 단면2차모멘트
- I22 - 합성전 강재단면의 2축방향(횡방향) 단면2차모멘트
- Iv33 - 합성후 강재단면의 3축방향(중방향) 단면2차모멘트
- Iv22 - 합성후 강재단면의 2축방향(횡방향) 단면2차모멘트

- Section G1-1



b	=	6080.000	mm
b1	=	100.000	mm
b2	=	2500.000	mm
b3	=	2700.000	mm
b1'	=	100.000	mm
b2'	=	2500.000	mm
b3'	=	2700.000	mm
Tc	=	250.000	mm
Th	=	50.000	mm
H	=	2600.000	mm
n	=	8	

① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 10.0	27000	1305.00	35235000	45981675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1 - 2700.0 X 10.0	27000	-1305.00	-35235000	45981675000	225000
TOTAL		133200		5145000	117173850000	35183950000

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 117173850000 + 35183950000 = 152357800000 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= 5145000 / 133200 = 38.63 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 152357800000 - 133200 \times 38.626^2 = 152159068581 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 10 / 12) + (2700^3 \times 10 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 131243995200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 10.000 / 2 + 10.000 / 2 = 2610.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2610^2) / (2 \times 2610/12 + 2512/10 + 2512/10) \\
&= 183423648143 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

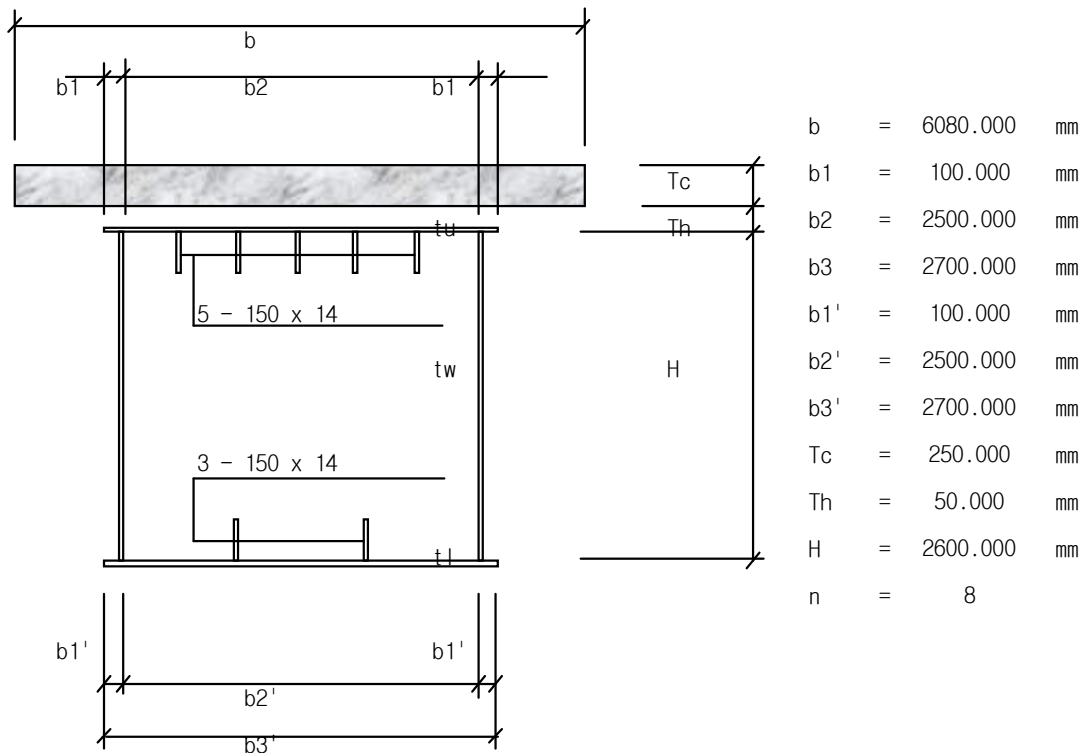
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 133200 + 1520000 / 8 = 323200 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 38.626 + 50.000 + 250.000 / 2 = 1436.37 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1436.374 \times 133200 / 323200 = 591.97 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1436.374 - 591.971 = 844.40 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 152159068581 + 7916666667 / 8 + 133200 \times 844.403^2 \\
&\quad + 1520000 / 8 \times 591.971^2 = 314704047860 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 131243995200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 716545328533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 250.000 / 8 = 41.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2610^2) / (2 \times 2610/12 + 2512/41.25 + 2512/10) \\
&= 230145931176 \text{ mm}^4
\end{aligned}$$

- Section G1-2



① 합성전 단면

구 분	규 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1 - 2700.0 X 10.0	27000	-1305.00	-35235000	45981675000	225000
TOTAL		138600		12224400	126454781400	35184113800

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 126454781400 + 35184113800 = 161638895200 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= 12224400 / 138600 = 88.20 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 161638895200 - 138600 \times 88.199^2 = 160560713704 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 12 / 12) + (2700^3 \times 10 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 134524495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 10.000 / 2 = 2611.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2611^2) / (2 \times 2611/12 + 2512/12 + 2512/10) \\
&= 192110202989 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

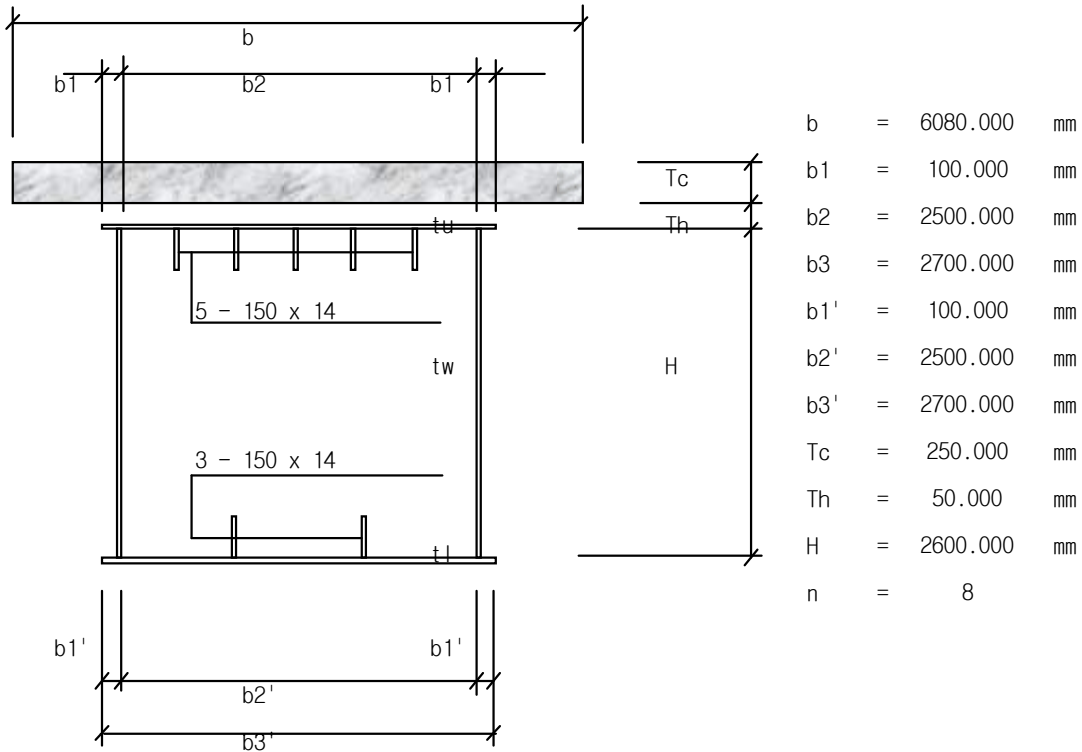
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 138600 + 1520000 / 8 = 328600 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 88.199 + 50.000 + 250.000 / 2 = 1386.80 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1386.801 \times 138600 / 328600 = 584.94 \text{ mm} \\
dvs &= dv - dvc = 1386.801 - 584.938 = 801.86 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 160560713704 + 7916666667 / 8 + 138600 \times 801.863^2 \\
&\quad + 1520000 / 8 \times 584.938^2 = 315676855267 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 134524495200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 719825828533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2611^2) / (2 \times 2611/12 + 2512/43.25 + 2512/10) \\
&= 231142004859 \text{ mm}^4
\end{aligned}$$

- Section G1-3



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1307.00	-49404600	64571812200	617400
TOTAL		149400		-1945200	145044918600	35184506200

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 145044918600 + 35184506200 = 180229424800 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -1945200 / 149400 = -13.02 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 180229424800 - 149400 \times (-13.02)^2 = 180204098140 \text{ mm}^4$$

$$I_{22} = (b3^3 \times tu / 12) + (b3'^3 \times tl / 12) + ((H \times tw^3 / 12) + (H \times tw \times (b2 / 2 + tw / 2)^2)) \times 2$$

$$= (2700^3 \times 12 / 12) + (2700^3 \times 14 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 141085495200 \text{ mm}^4$$

- 비틀림 강성

$$bk = b2 + tw / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 14.000 / 2 = 2613.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2613^2) / (2 \times 2613/12 + 2512/12 + 2512/14) \\
&= 209080173861 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

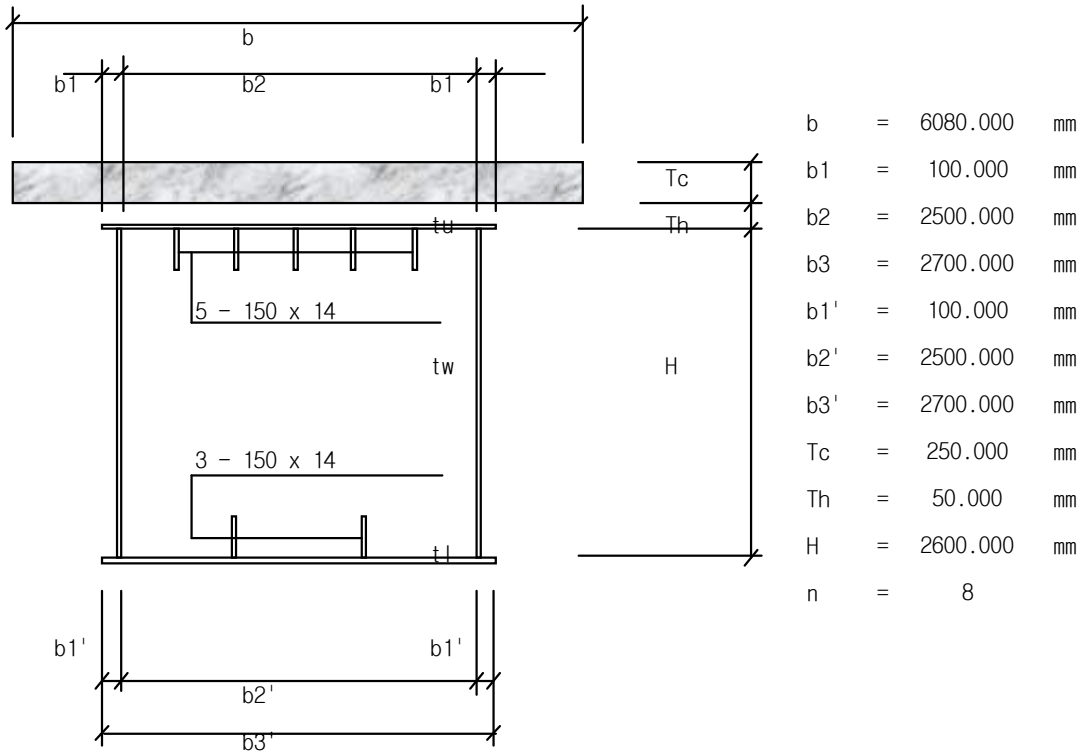
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 149400 + 1520000 / 8 = 339400 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 13.020 + 50.000 + 250.000 / 2 = 1488.02 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1488.020 \times 149400 / 339400 = 655.01 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1488.020 - 655.009 = 833.01 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 180204098140 + 7916666667 / 8 + 149400 \times 833.011^2 \\
&\quad + 1520000 / 8 \times 655.009^2 = 366380446103 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 141085495200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 726386828533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2613^2) / (2 \times 2613/12 + 2512/43.25 + 2512/14) \\
&= 256068931132 \text{ mm}^4
\end{aligned}$$

- Section G1-4



① 합성전 단면

구 분	규 격					As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	lo(mm ⁴)
UPPER FL.	1	-	2700.0	X	12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5	-	150.0	X	14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2	-	2600.0	X	10.0	52000				29293333333
LOWER RIB	3	-	150.0	X	14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1	-	2700.0	X	14.0	37800	-1307.00	-49404600	64571812200	617400
TOTAL						139000		-1945200	145044918600	29325839533

$$I_s = \sum A s^2 + \sum I_o = 145044918600 + 29325839533 = 174370758133 \text{ mm}^4$$

$$\delta s = \frac{\sum A_s Y}{\sum A_s} = \frac{-1945200}{139000} = -13.99 \text{ mm}$$

$$I_{33} = I_{s'} - \sum A_s \times \delta s^2$$

$$= 174370758133 - 139000 \times -13.994^2 = 174343536529 \text{ mm}^4$$

$$\begin{aligned}
 I_{22} &= (b3^3 \times t_u / 12) + (b3^{13} \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b2 / 2 + t_w / 2)^2)) \times 2 \\
 &= (2700^3 \times 12 / 12) + (2700^3 \times 14 / 12) + ((2600 \times 10^3 / 12) \\
 &\quad + (2600 \times 10 \times (2500 / 2 + 10 / 2)^2)) \times 2 = 124548233333 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2 = 2500.000 + 10.000 / 2 \times 2 = 2510.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 14.000 / 2 = 2613.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2510^2 \times 2613^2) / (2 \times 2613/10 + 2510/12 + 2510/14) \\
&= 188861270224 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

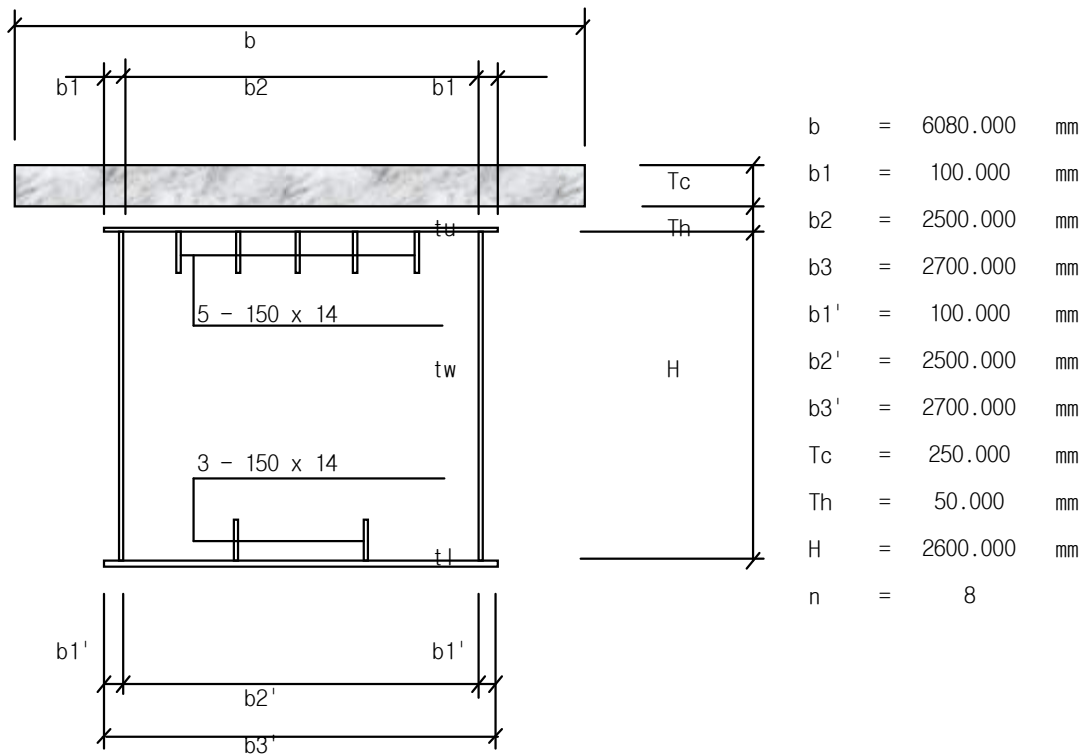
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 139000 + 1520000 / 8 = 329000 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 13.994 + 50.000 + 250.000 / 2 = 1488.99 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1488.994 \times 139000 / 329000 = 629.09 \text{ mm} \\
dvs &= dv - dvc = 1488.994 - 629.089 = 859.91 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 174343536529 + 7916666667 / 8 + 139000 \times 859.905^2 \\
&\quad + 1520000 / 8 \times 629.089^2 = 353307931275 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 124548233333 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 709849566667 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2510^2 \times 2613^2) / (2 \times 2613/10 + 2510/43.25 + 2510/14) \\
&= 226421755134 \text{ mm}^4
\end{aligned}$$

- Section G1-5



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 16.0	43200	1308.00	56505600	73909324800	921600
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 10.0	52000				29293333333
LOWER RIB	3 - 150.0 X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1307.00	-49404600	64571812200	617400
TOTAL		149800		12246000	163691637000	29326372333

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 163691637000 + 29326372333 = 193018009333 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= 12246000 / 149800 = 81.75 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 193018009333 - 149800 \times 81.749^2 = 192016911096 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 16 / 12) + (2700^3 \times 14 / 12) + ((2600 \times 10^3 / 12) + (2600 \times 10 \times (2500 / 2 + 10 / 2)^2)) \times 2 = 131109233333 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 10.000 / 2 \times 2 = 2510.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 16.000 / 2 + 14.000 / 2 = 2615.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2510^2 \times 2615^2) / (2 \times 2615/10 + 2510/16 + 2510/14) \\
&= 200574819617 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

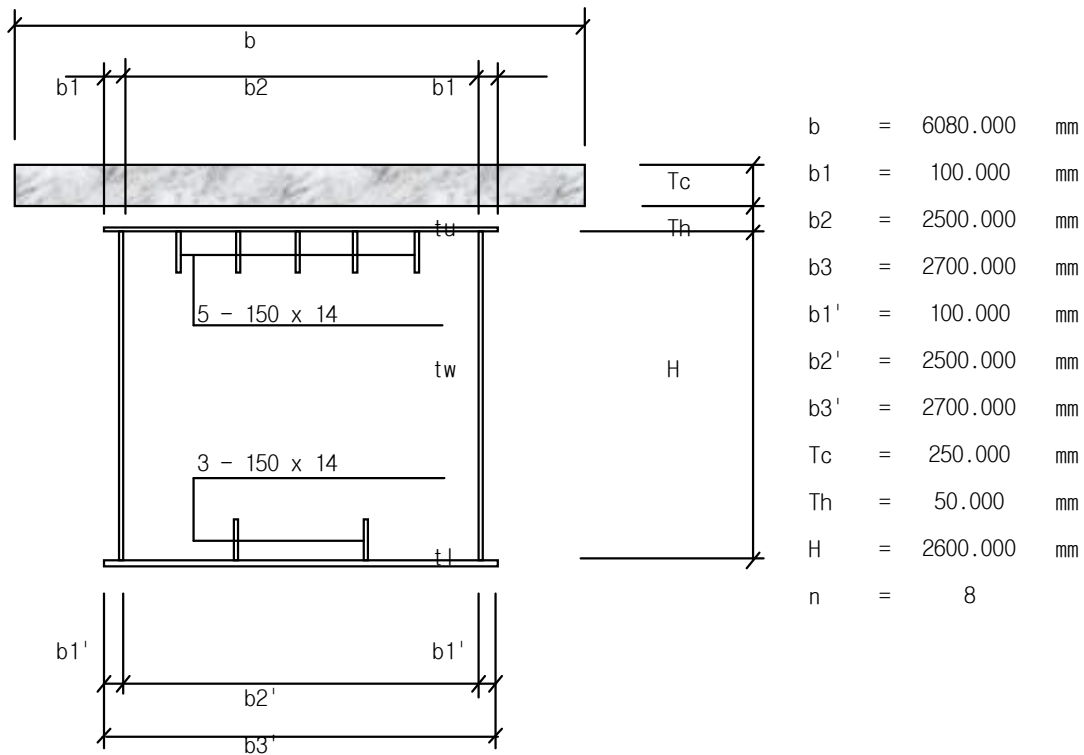
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 149800 + 1520000 / 8 = 339800 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 81.749 + 50.000 + 250.000 / 2 = 1393.25 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1393.251 \times 149800 / 339800 = 614.21 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1393.251 - 614.211 = 779.04 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 192016911096 + 7916666667 / 8 + 149800 \times 779.040^2 \\
&\quad + 1520000 / 8 \times 614.211^2 = 355599091295 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 131109233333 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 716410566667 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 16.000 + 250.000 / 8 = 47.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2510^2 \times 2615^2) / (2 \times 2615/10 + 2510/47.25 + 2510/14) \\
&= 228123266465 \text{ mm}^4
\end{aligned}$$

- Section G1-6



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 16.0	43200	1308.00	56505600	73909324800	921600
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 10.0	52000				29293333333
LOWER RIB	3 - 150.0 X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL		171400		-16222800	201211852200	29328150733

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 201211852200 + 29328150733 = 230540002933 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -16222800 / 171400 = -94.65 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 230540002933 - 171400 \times (-94.649)^2 = 229004534790 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 16 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 10^3 / 12) + (2600 \times 10 \times (2500 / 2 + 10 / 2)^2)) \times 2$$

$$= 14423123333 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 10.000 / 2 \times 2 = 2510.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 16.000 / 2 + 22.000 / 2 = 2619.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2510^2 \times 2619^2) / (2 \times 2619/10 + 2510/16 + 2510/22) \\
&= 217489953818 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

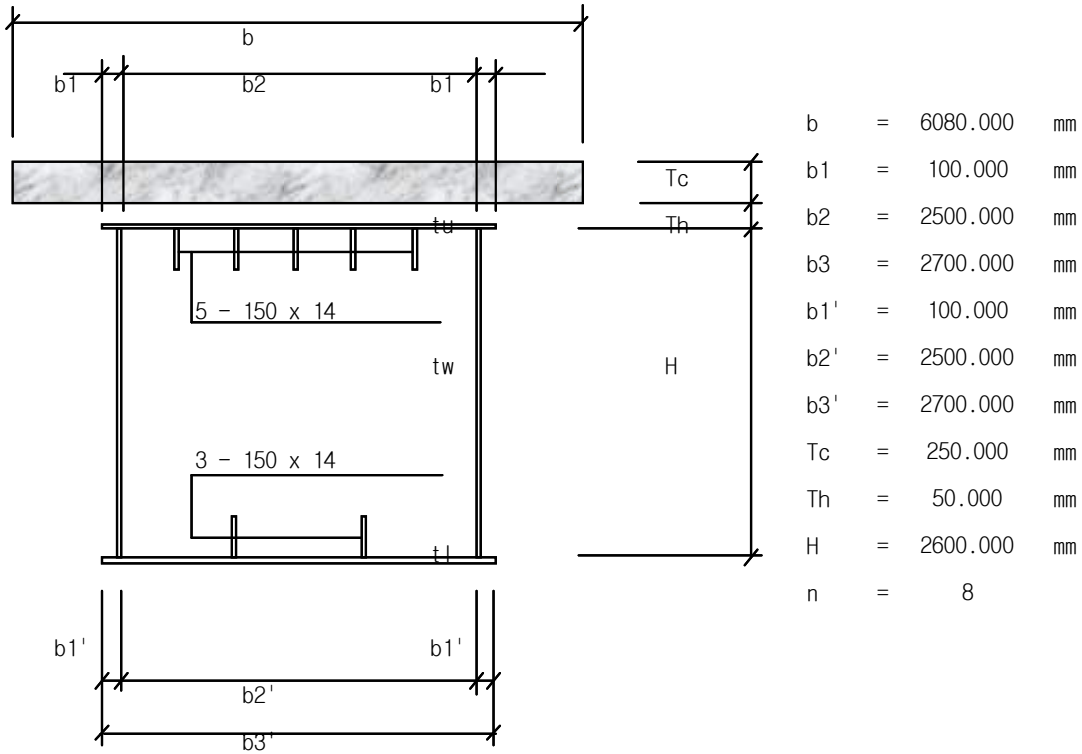
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 171400 + 1520000 / 8 = 361400 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 94.649 + 50.000 + 250.000 / 2 = 1569.65 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1569.649 \times 171400 / 361400 = 744.43 \text{ mm} \\
dvs &= dv - dvc = 1569.649 - 744.432 = 825.22 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 229004534790 + 7916666667 / 8 + 171400 \times 825.217^2 \\
&\quad + 1520000 / 8 \times 744.432^2 = 452008567756 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 144231233333 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 729532566667 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 16.000 + 250.000 / 8 = 47.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2510^2 \times 2619^2) / (2 \times 2619/10 + 2510/47.25 + 2510/22) \\
&= 250145366830 \text{ mm}^4
\end{aligned}$$

- Section G1-7



① 합성전 단면

구 분	규 격				As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1	-	2700.0	X 16.0	43200	1308.00	56505600	73909324800	921600
UPPER RIB	5	-	150.0	X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2	-	2600.0	X 12.0	62400				35152000000
LOWER RIB	3	-	150.0	X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1	-	2700.0	X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL					181800		-16222800	201211852200	35186817400

$$I_s' = \sum A s Y^2 + \sum I_o = 201211852200 + 35186817400 = 236398669600 \text{ mm}^4$$

$$\delta s = \frac{\sum AsY}{\sum As} = \frac{-16222800}{181800} = -89.23 \text{ mm}$$

$$I_{33} = I_{s'} - \sum A_s \times \delta s^2$$

$$= 236398669600 - 181800 \times -89.234^2 = 234951039018 \text{ mm}^4$$

$$\begin{aligned}
 I_{22} &= (b_3^3 \times t_u / 12) + (b_3^{13} \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2 \\
 &= (2700^3 \times 16 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) \\
 &\quad + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 160768495200 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 16.000 / 2 + 22.000 / 2 = 2619.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2619^2) / (2 \times 2619/12 + 2512/16 + 2512/22) \\
&= 244642677074 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

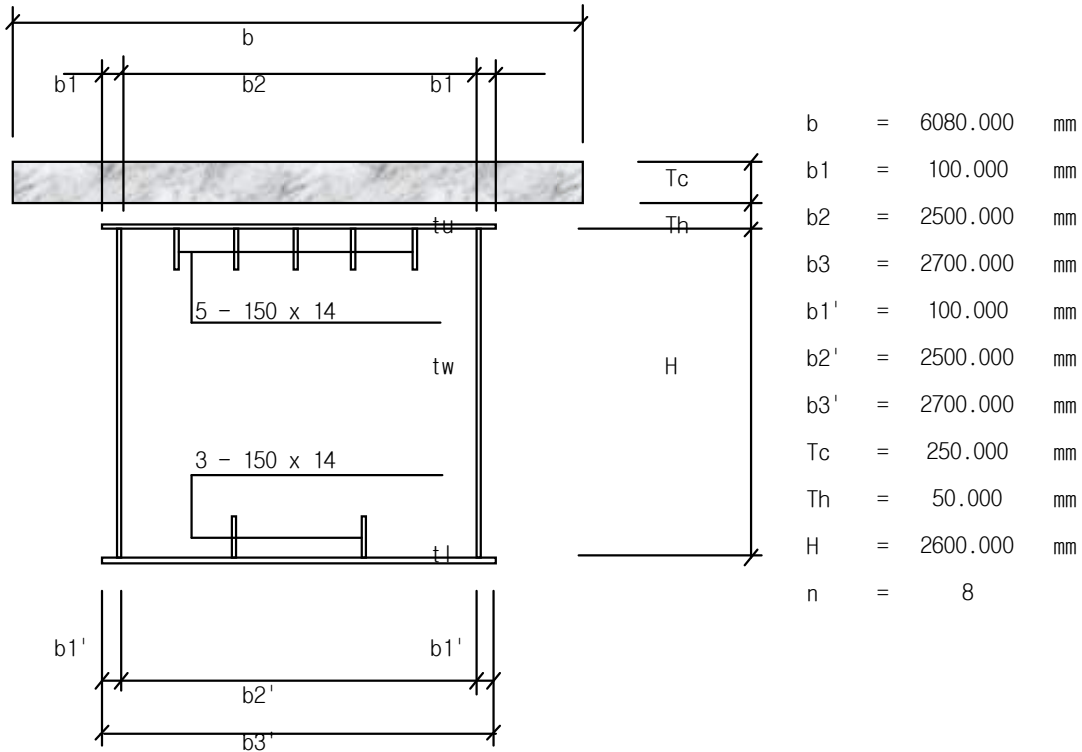
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 181800 + 1520000 / 8 = 371800 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 89.234 + 50.000 + 250.000 / 2 = 1564.23 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1564.234 \times 181800 / 371800 = 764.87 \text{ mm} \\
dvs &= dv - dvc = 1564.234 - 764.868 = 799.37 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 234951039018 + 7916666667 / 8 + 181800 \times 799.367^2 \\
&\quad + 1520000 / 8 \times 764.868^2 = 463262752423 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 160768495200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 746069828533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 16.000 + 250.000 / 8 = 47.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2619^2) / (2 \times 2619/12 + 2512/47.25 + 2512/22) \\
&= 286710884196 \text{ mm}^4
\end{aligned}$$

- Section G1-8



① 합성전 단면

구 분	규 격				As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1	-	2700.0	X 12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5	-	150.0	X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2	-	2600.0	X 12.0	62400				35152000000
LOWER RIB	3	-	150.0	X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1	-	2700.0	X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL					171000		-30414000	182565133800	35186284600

$$|s'| = \sum A s Y^2 + \sum l o$$

$$= 182565133800 + 35186284600 = 217751418400 \text{ mm}^4$$

$$\delta s = \frac{\sum A_s Y}{\sum A_s} = \frac{-30414000}{171000} = -177.86 \text{ mm}$$

$$I_{33} = I_{s'} - \sum A_s \times \delta s^2$$

$$= 217751418400 - 171000 \times -177.860^2 = 212341995032 \text{ mm}^4$$

$$\begin{aligned}
 I_{22} &= (b3^3 \times t_u / 12) + (b3^{13} \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b2 / 2 + t_w / 2)^2)) \times 2 \\
 &= (2700^3 \times 12 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) \\
 &\quad + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 154207495200 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 22.000 / 2 = 2617.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2617^2) / (2 \times 2617/12 + 2512/12 + 2512/22) \\
&= 227549022588 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

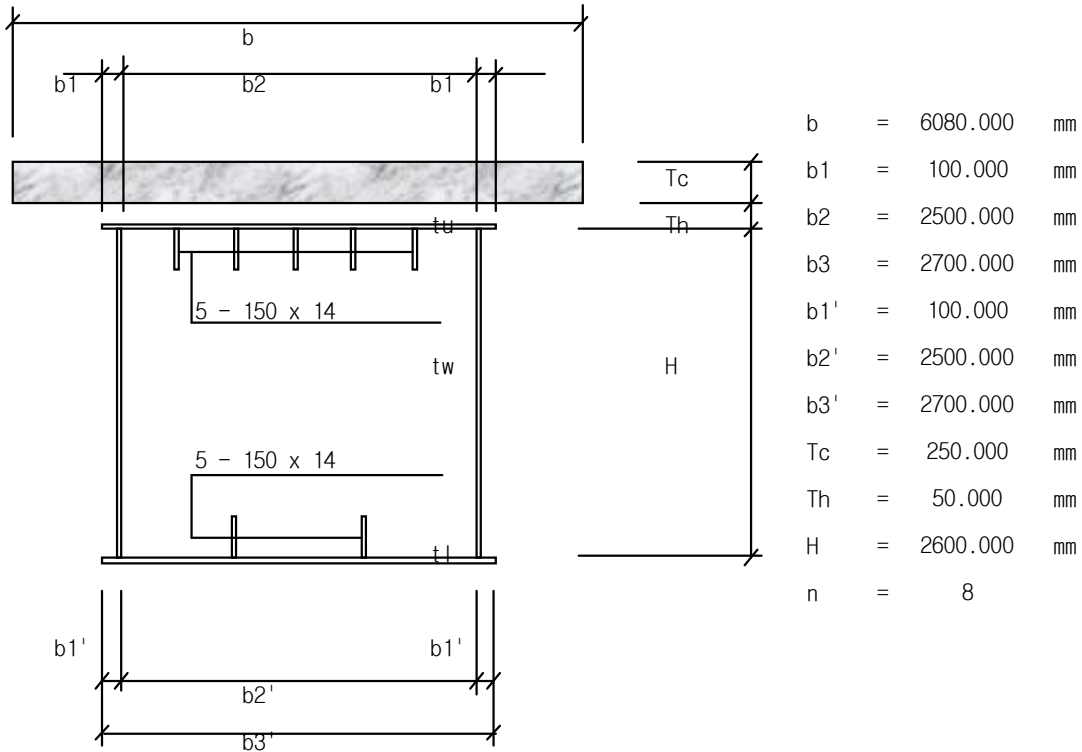
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 171000 + 1520000 / 8 = 361000 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - (-177.860) + 50.000 + 250.000 / 2 = 1652.86 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1652.860 \times 171000 / 361000 = 782.93 \text{ mm} \\
dvs &= dv - dvc = 1652.860 - 782.934 = 869.93 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 212341995032 + 7916666667 / 8 + 171000 \times 869.926^2 \\
&\quad + 1520000 / 8 \times 782.934^2 = 459206630138 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 154207495200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 739508828533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2617^2) / (2 \times 2617/12 + 2512/43.25 + 2512/22) \\
&= 284116534224 \text{ mm}^4
\end{aligned}$$

- Section G1-9



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1307.00	-49404600	64571812200	617400
TOTAL		153600		-7090200	151347543600	35192381200

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 151347543600 + 35192381200 = 186539924800 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -7090200 / 153600 = -46.16 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 186539924800 - 153600 \times (-46.16)^2 = 186212640060 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 12 / 12) + (2700^3 \times 14 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 141085495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 14.000 / 2 = 2613.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2613^2) / (2 \times 2613/12 + 2512/12 + 2512/14) \\
&= 209080173861 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

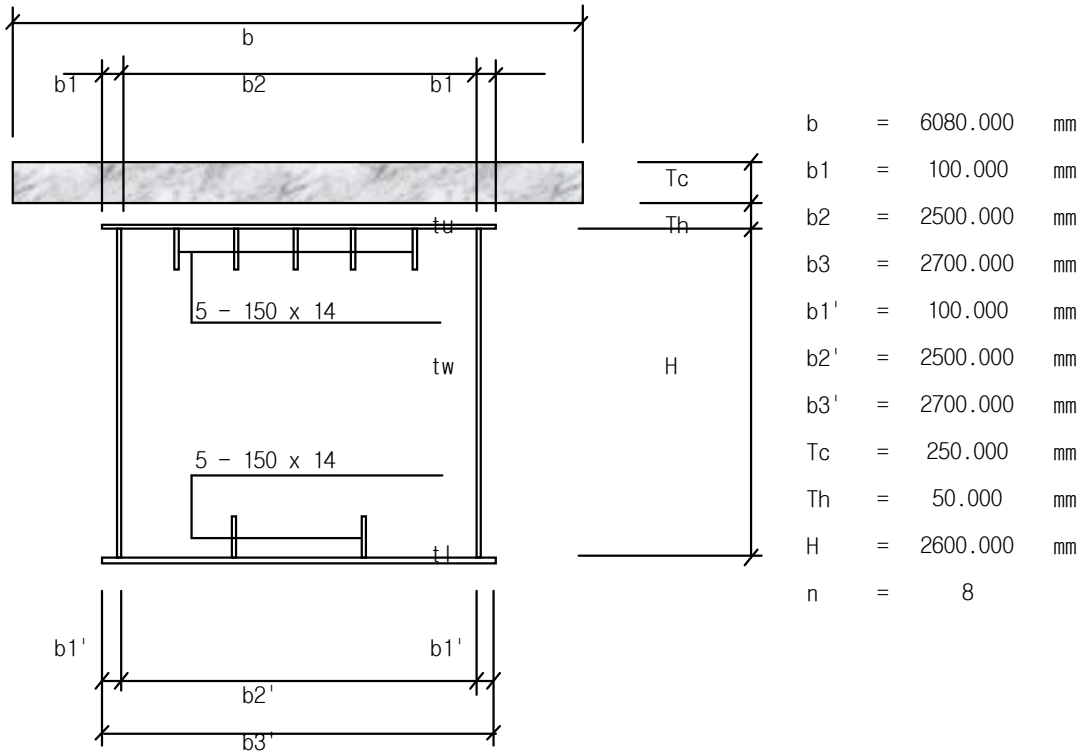
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 153600 + 1520000 / 8 = 343600 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 46.160 + 50.000 + 250.000 / 2 = 1521.16 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1521.160 \times 153600 / 343600 = 680.01 \text{ mm} \\
dvs &= dv - dvc = 1521.160 - 680.006 = 841.15 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 186212640060 + 7916666667 / 8 + 153600 \times 841.154^2 \\
&\quad + 1520000 / 8 \times 680.006^2 = 383737966119 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 141085495200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 726386828533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2613^2) / (2 \times 2613/12 + 2512/43.25 + 2512/14) \\
&= 256068931132 \text{ mm}^4
\end{aligned}$$

- Section G1-10



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 10.0	27000	1305.00	35235000	45981675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1307.00	-49404600	64571812200	617400
TOTAL		148200		-14169600	142066612200	35192217400

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 142066612200 + 35192217400 = 177258829600 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -14169600 / 148200 = -95.61 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 177258829600 - 148200 \times (-95.61)^2 = 175904055213 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 10 / 12) + (2700^3 \times 14 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 137804995200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 10.000 / 2 + 14.000 / 2 = 2612.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2612^2) / (2 \times 2612/12 + 2512/10 + 2512/14) \\
&= 198859718191 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

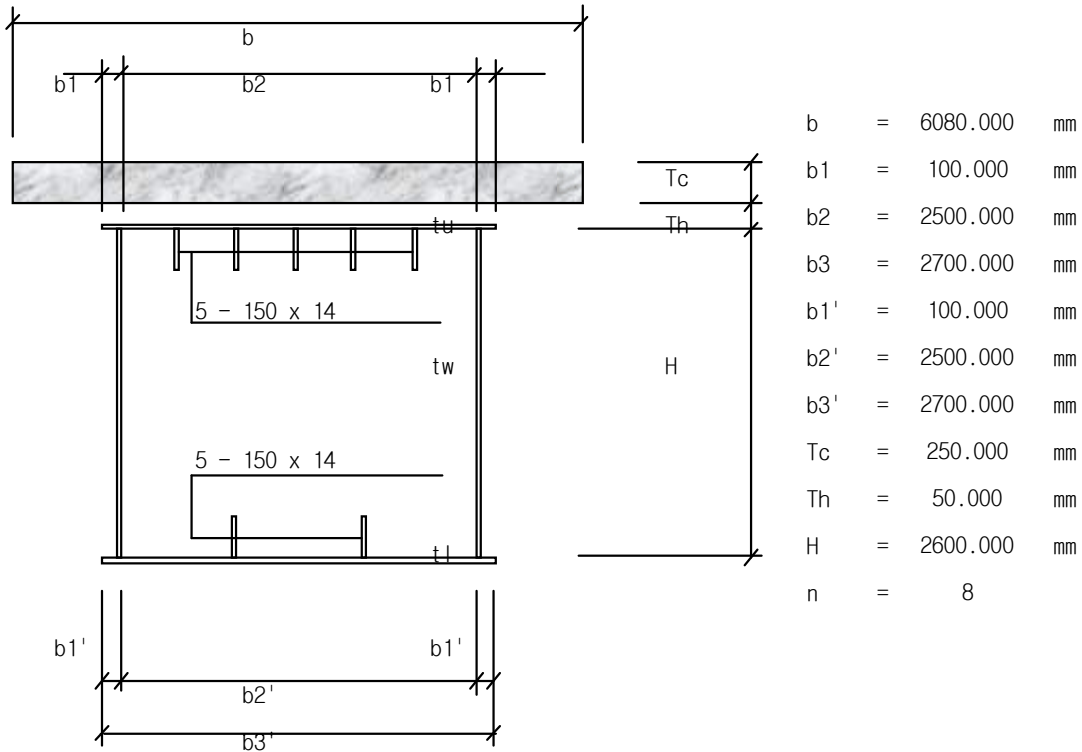
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 148200 + 1520000 / 8 = 338200 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 95.611 + 50.000 + 250.000 / 2 = 1570.61 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1570.611 \times 148200 / 338200 = 688.25 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1570.611 - 688.245 = 882.37 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 175904055213 + 7916666667 / 8 + 148200 \times 882.366^2 \\
&\quad + 1520000 / 8 \times 688.245^2 = 382277188764 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 137804995200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 723106328533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 250.000 / 8 = 41.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2612^2) / (2 \times 2612/12 + 2512/41.25 + 2512/14) \\
&= 254869649249 \text{ mm}^4
\end{aligned}$$

- Section G1-11



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 10.0	27000	1305.00	35235000	45981675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1306.00	-42314400	55262606400	388800
TOTAL		142800		-7079400	132757406400	35191988800

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 132757406400 + 35191988800 = 167949395200 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -7079400 / 142800 = -49.58 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 167949395200 - 142800 \times (-49.576)^2 = 167598429483 \text{ mm}^4$$

$$I_{22} = (b3^3 \times tu / 12) + (b3'^3 \times tl / 12) + ((H \times tw^3 / 12) + (H \times tw \times (b2 / 2 + tw / 2)^2)) \times 2$$

$$= (2700^3 \times 10 / 12) + (2700^3 \times 12 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 134524495200 \text{ mm}^4$$

- 비틀림 강성

$$bk = b2 + tw / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 10.000 / 2 + 12.000 / 2 = 2611.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2611^2) / (2 \times 2611/12 + 2512/10 + 2512/12) \\
&= 192110202989 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

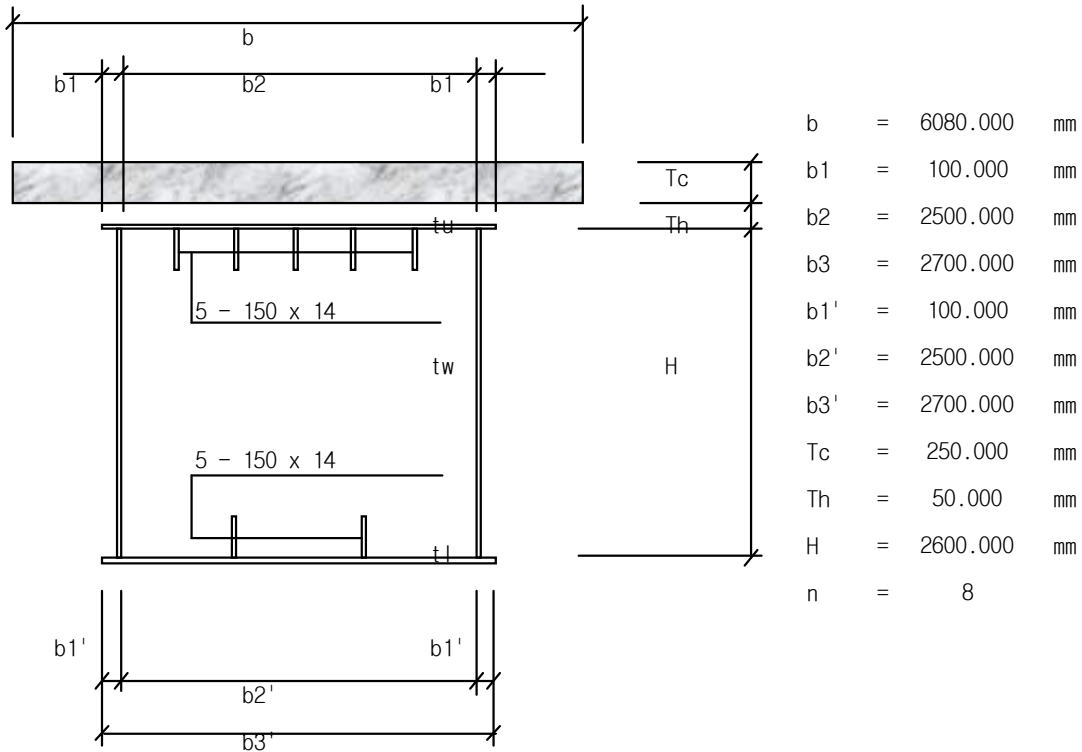
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 142800 + 1520000 / 8 = 332800 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 49.576 + 50.000 + 250.000 / 2 = 1524.58 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1524.576 \times 142800 / 332800 = 654.17 \text{ mm} \\
dvs &= dv - dvc = 1524.576 - 654.175 = 870.40 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 167598429483 + 7916666667 / 8 + 142800 \times 870.401^2 \\
&\quad + 1520000 / 8 \times 654.175^2 = 358082437955 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 134524495200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 719825828533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 250.000 / 8 = 41.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2611^2) / (2 \times 2611/12 + 2512/41.25 + 2512/12) \\
&= 243937975649 \text{ mm}^4
\end{aligned}$$

- Section G1-12



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 18.0	48600	1309.00	63617400	83275176600	1312200
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1306.00	-42314400	55262606400	388800
TOTAL		164400		21303000	170050908000	35193076000

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 170050908000 + 35193076000 = 205243984000 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= 21303000 / 164400 = 129.58 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 205243984000 - 164400 \times 129.58^2 = 202483535040 \text{ mm}^4$$

$$I_{22} = (b3^3 \times t_u / 12) + (b3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 18 / 12) + (2700^3 \times 12 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 147646495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 18.000 / 2 + 12.000 / 2 = 2615.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2615^2) / (2 \times 2615/12 + 2512/18 + 2512/12) \\
&= 219951382706 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

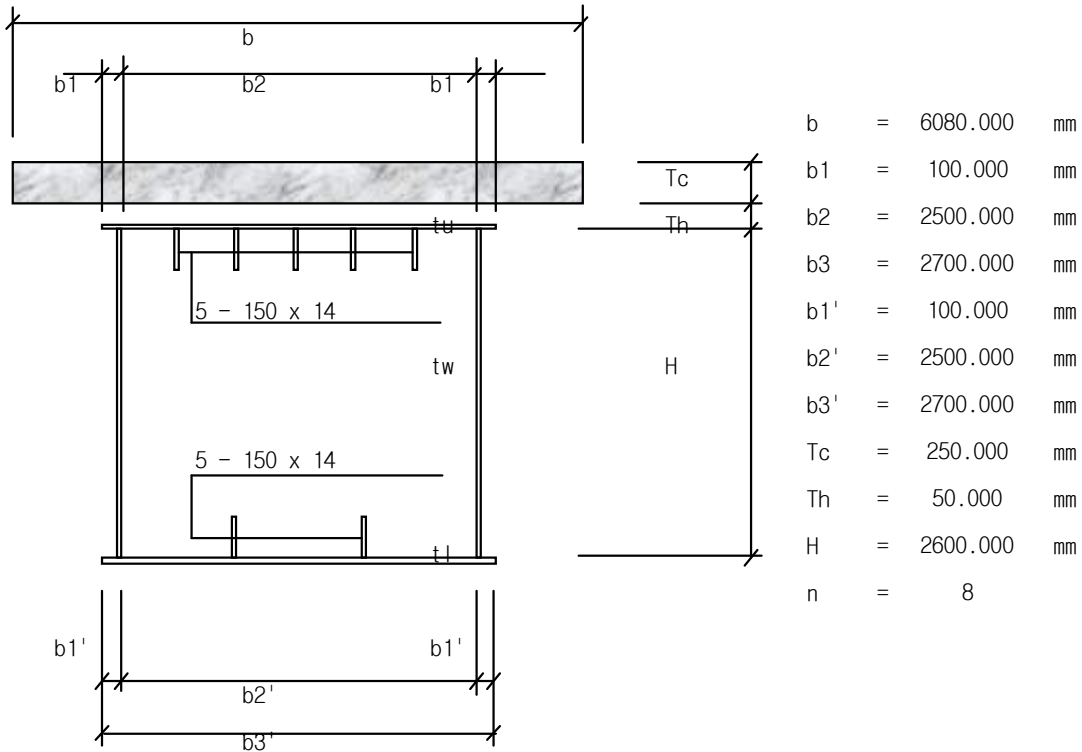
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 164400 + 1520000 / 8 = 354400 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 129.580 + 50.000 + 250.000 / 2 = 1345.42 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1345.420 \times 164400 / 354400 = 624.12 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1345.420 - 624.117 = 721.30 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 202483535040 + 7916666667 / 8 + 164400 \times 721.303^2 \\
&\quad + 1520000 / 8 \times 624.117^2 = 363015940897 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 147646495200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 732947828533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 18.000 + 250.000 / 8 = 49.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2615^2) / (2 \times 2615/12 + 2512/49.25 + 2512/12) \\
&= 247928387787 \text{ mm}^4
\end{aligned}$$

- Section G1-13



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 18.0	48600	1309.00	63617400	83275176600	1312200
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL		191400		-14256000	216880329000	35195083000

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 216880329000 + 35195083000 = 252075412000 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -14256000 / 191400 = -74.48 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 252075412000 - 191400 \times (-74.483)^2 = 251013585793 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 18 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 164048995200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 18.000 / 2 + 22.000 / 2 = 2620.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2620^2) / (2 \times 2620/12 + 2512/18 + 2512/22) \\
&= 250956541032 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

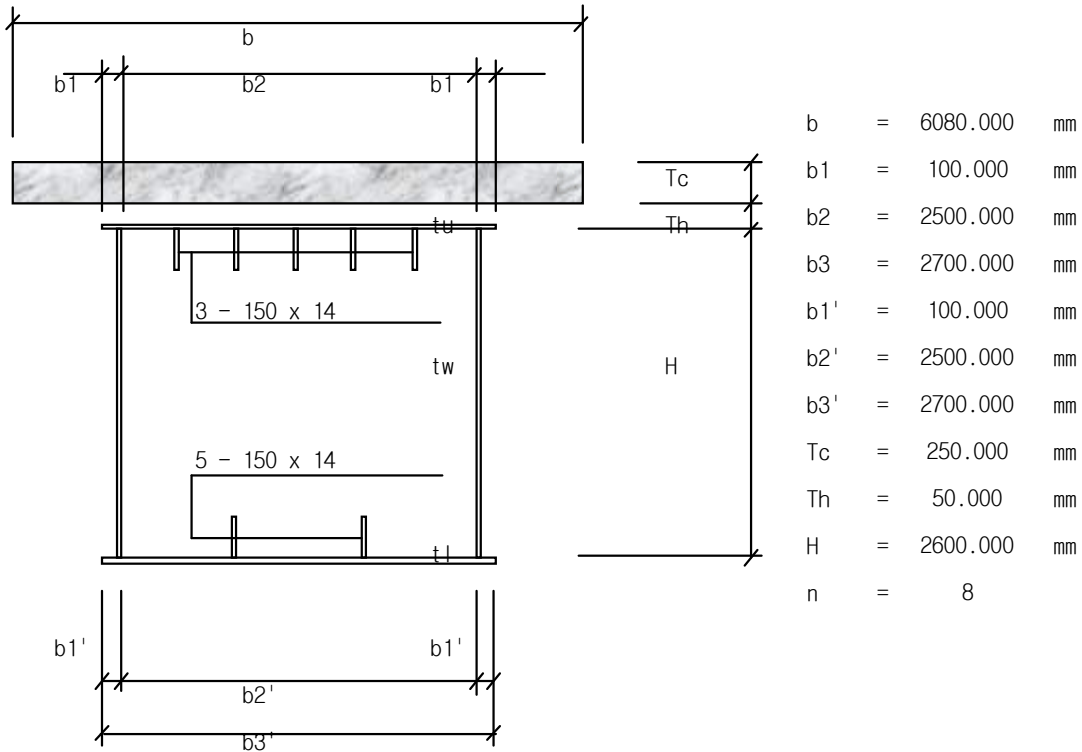
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 191400 + 1520000 / 8 = 381400 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 74.483 + 50.000 + 250.000 / 2 = 1549.48 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1549.483 \times 191400 / 381400 = 777.59 \text{ mm} \\
dvs &= dv - dvc = 1549.483 - 777.585 = 771.90 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 251013585793 + 7916666667 / 8 + 191400 \times 771.898^2 \\
&\quad + 1520000 / 8 \times 777.585^2 = 480925596314 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 164048995200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 749350328533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 18.000 + 250.000 / 8 = 49.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2620^2) / (2 \times 2620/12 + 2512/49.25 + 2512/22) \\
&= 287879678919 \text{ mm}^4
\end{aligned}$$

- Section G1-14



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 18.0	48600	1309.00	63617400	83275176600	1312200
UPPER RIB	3 - 150.0 X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL		187200		-19401000	210577704000	35187208000

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 210577704000 + 35187208000 = 245764912000 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -19401000 / 187200 = -103.64 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 245764912000 - 187200 \times (-103.638)^2 = 243754234644 \text{ mm}^4$$

$$I_{22} = (b3^3 \times tu / 12) + (b3'^3 \times tl / 12) + ((H \times tw^3 / 12) + (H \times tw \times (b2 / 2 + tw / 2)^2)) \times 2$$

$$= (2700^3 \times 18 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 164048995200 \text{ mm}^4$$

- 비틀림 강성

$$bk = b2 + tw / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 18.000 / 2 + 22.000 / 2 = 2620.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2620^2) / (2 \times 2620/12 + 2512/18 + 2512/22) \\
&= 250956541032 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

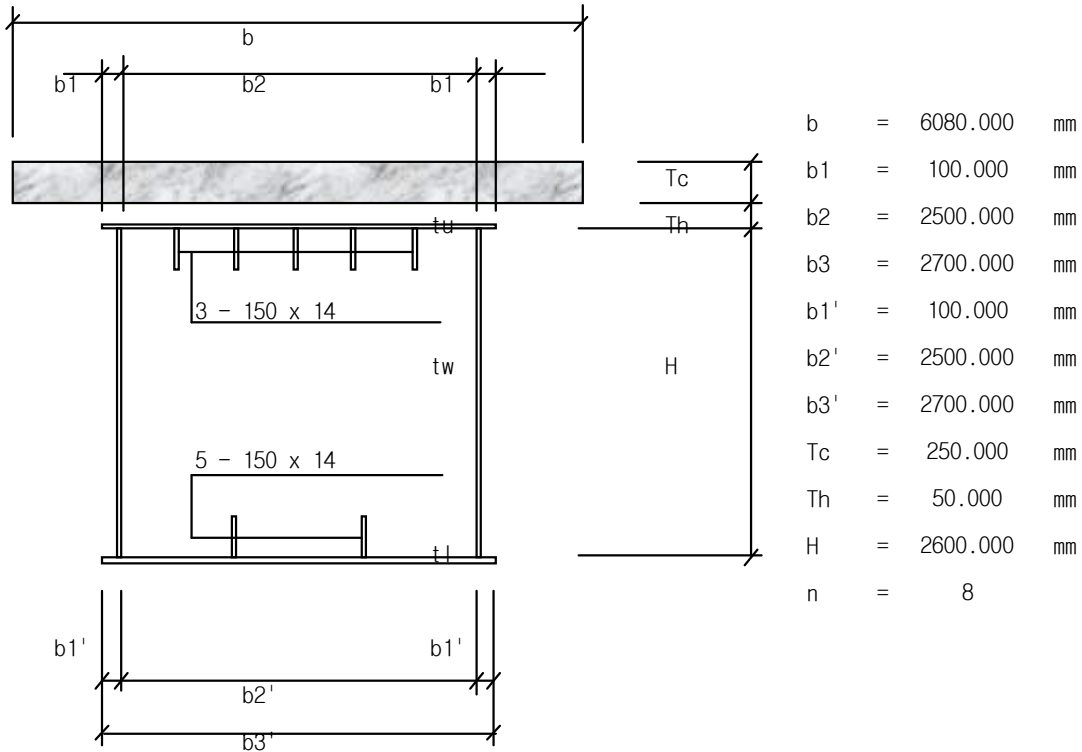
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 187200 + 1520000 / 8 = 377200 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 103.638 + 50.000 + 250.000 / 2 = 1578.64 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1578.638 \times 187200 / 377200 = 783.46 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1578.638 - 783.460 = 795.18 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 243754234644 + 7916666667 / 8 + 187200 \times 795.178^2 \\
&\quad + 1520000 / 8 \times 783.460^2 = 479735650421 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 164048995200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 749350328533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 18.000 + 250.000 / 8 = 49.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2620^2) / (2 \times 2620/12 + 2512/49.25 + 2512/22) \\
&= 287879678919 \text{ mm}^4
\end{aligned}$$

- Section G1-15



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 28.0	75600	1314.00	99338400	130530657600	4939200
UPPER RIB	3 - 150.0 X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL		214200		16320000	257833185000	35190835000

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 257833185000 + 35190835000 = 293024020000 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= 16320000 / 214200 = 76.19 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 293024020000 - 214200 \times 76.19^2 = 291780591429 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 28 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 180451495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 28.000 / 2 + 22.000 / 2 = 2625.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2625^2) / (2 \times 2625/12 + 2512/28 + 2512/22) \\
&= 271163705148 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

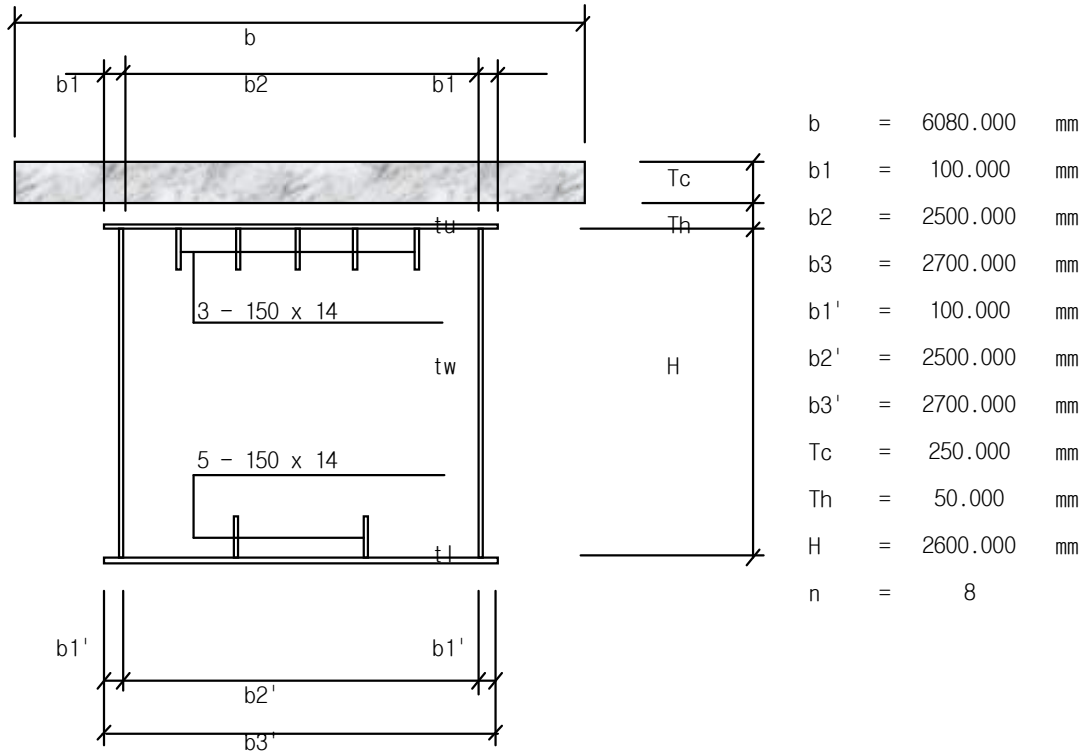
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 214200 + 1520000 / 8 = 404200 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 76.190 + 50.000 + 250.000 / 2 = 1398.81 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1398.810 \times 214200 / 404200 = 741.28 \text{ mm} \\
dvs &= dv - dvc = 1398.810 - 741.279 = 657.53 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 291780591429 + 7916666667 / 8 + 214200 \times 657.530^2 \\
&\quad + 1520000 / 8 \times 741.279^2 = 489782737054 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 180451495200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 765752828533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 28.000 + 250.000 / 8 = 59.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2625^2) / (2 \times 2625/12 + 2512/59.25 + 2512/22) \\
&= 292761580816 \text{ mm}^4
\end{aligned}$$

- Section G1-16



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 28.0	75600	1314.00	99338400	130530657600	4939200
UPPER RIB	3 - 150.0 X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 32.0	86400	-1316.00	-113702400	149632358400	7372800
TOTAL		241200		-19509000	305373516000	35195812000

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 305373516000 + 35195812000 = 340569328000 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -19509000 / 241200 = -80.88 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 340569328000 - 241200 \times (-80.88)^2 = 338991379903 \text{ mm}^4$$

$$I_{22} = (b3^3 \times tu / 12) + (b3'^3 \times tl / 12) + ((H \times tw^3 / 12) + (H \times tw \times (b2 / 2 + tw / 2)^2)) \times 2$$

$$= (2700^3 \times 28 / 12) + (2700^3 \times 32 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 196853995200 \text{ mm}^4$$

- 비틀림 강성

$$bk = b2 + tw / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
 H_k &= H + t_u / 2 + t_l / 2 \\
 &= 2600.000 + 28.000 / 2 + 32.000 / 2 = 2630.00 \text{ mm} \\
 K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
 &= (4 \times 2512^2 \times 2630^2) / (2 \times 2630/12 + 2512/28 + 2512/32) \\
 &= 287836494039 \text{ mm}^4
 \end{aligned}$$

② 합성후 단면

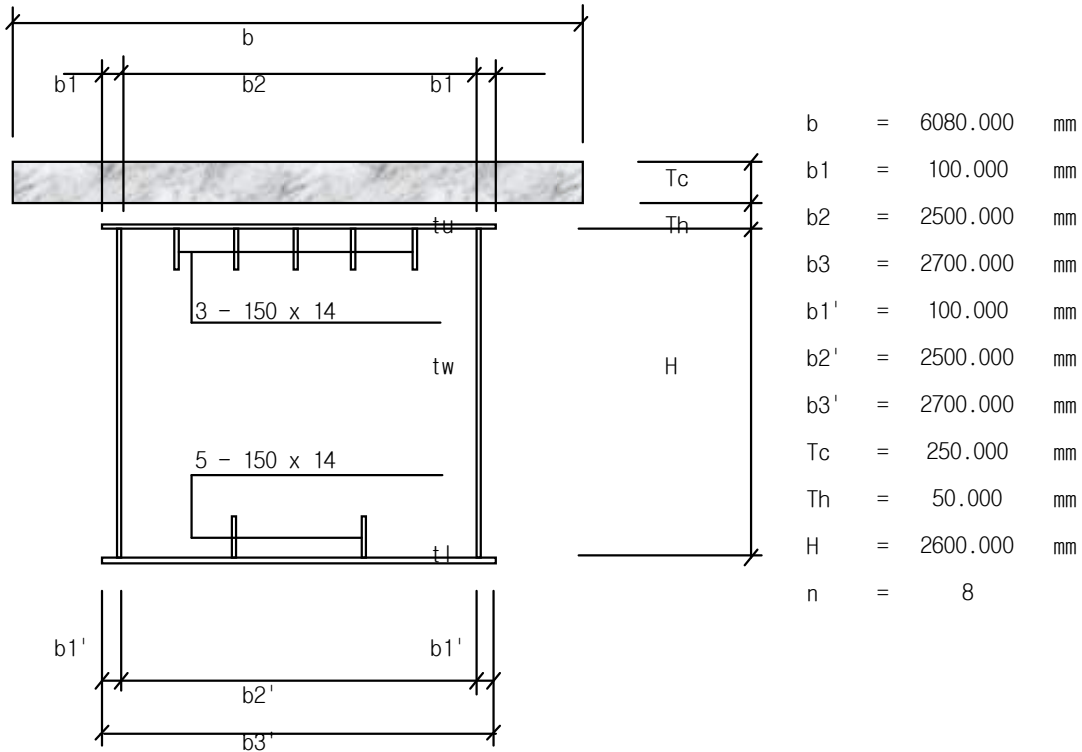
$$\begin{aligned}
 A_c &= b \times T_c \\
 &= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
 A_v &= \sum A_s + A_c/N \\
 &= 241200 + 1520000 / 8 = 431200 \text{ mm}^2 \\
 I_c &= b \times T_c^3 / 12 \\
 &= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
 d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
 &= 2600.000 / 2 - 80.883 + 50.000 + 250.000 / 2 = 1555.88 \text{ mm} \\
 d_{vc} &= d_v \cdot \sum A_s / A_v \\
 &= 1555.883 \times 241200 / 431200 = 870.31 \text{ mm} \\
 d_{vs} &= d_v - d_{vc} = 1555.883 - 870.313 = 685.57 \text{ mm} \\
 I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
 &= 338991379903 + 7916666667 / 8 + 241200 \times 685.570^2 \\
 &\quad + 1520000 / 8 \times 870.313^2 = 597260989068 \text{ mm}^4 \\
 I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
 &= 196853995200 + 6080.000^3 \\
 &\quad \times 250.000 / 12 / 8 = 782155328533 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
 t_{cu} &= t_u + T_c / N \\
 &= 28.000 + 250.000 / 8 = 59.25 \text{ mm} \\
 K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
 &= (4 \times 2512^2 \times 2630^2) / (2 \times 2630/12 + 2512/59.25 + 2512/32) \\
 &= 312190964911 \text{ mm}^4
 \end{aligned}$$

- Section G1-17



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 28.0	75600	1314.00	99338400	130530657600	4939200
UPPER RIB	3 - 150.0 X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 28.0	75600	-1314.00	-99338400	130530657600	4939200
TOTAL		230400		-5145000	286271815200	35193378400

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 286271815200 + 35193378400 = 321465193600 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -5145000 / 230400 = -22.33 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 321465193600 - 230400 \times (-22.33)^2 = 321350301998 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 28 / 12) + (2700^3 \times 28 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 190292995200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 28.000 / 2 + 28.000 / 2 = 2628.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2628^2) / (2 \times 2628/12 + 2512/28 + 2512/28) \\
&= 282334051749 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

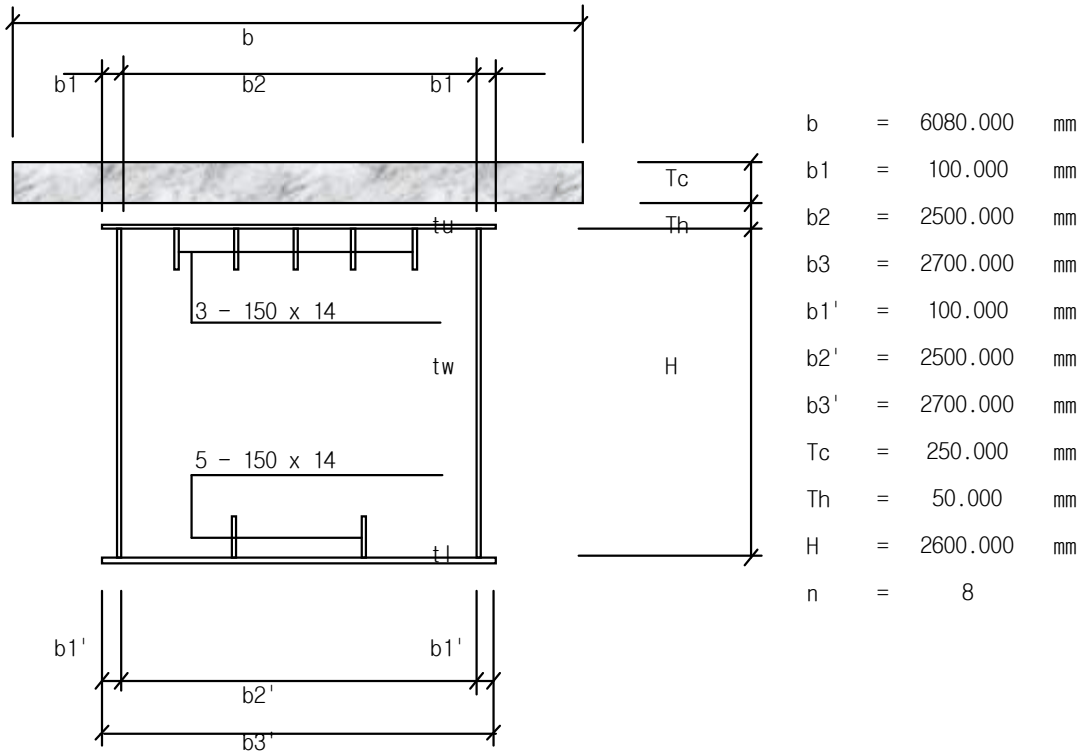
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c / N \\
&= 230400 + 1520000 / 8 = 420400 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 22.331 + 50.000 + 250.000 / 2 = 1497.33 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1497.331 \times 230400 / 420400 = 820.61 \text{ mm} \\
dvs &= dv - dvc = 1497.331 - 820.611 = 676.72 \text{ mm} \\
I_{v33} &= I_{33} + I_c / N + \sum A_s \cdot dvs^2 + A_c / N \cdot dvc^2 \\
&= 321350301998 + 7916666667 / 8 + 230400 \times 676.719^2 \\
&\quad + 1520000 / 8 \times 820.611^2 = 555797929823 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 190292995200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 775594328533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 28.000 + 250.000 / 8 = 59.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2628^2) / (2 \times 2628/12 + 2512/59.25 + 2512/28) \\
&= 305767013264 \text{ mm}^4
\end{aligned}$$

- Section G1-18



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 18.0	48600	1309.00	63617400	83275176600	1312200
UPPER RIB	3 - 150.0 X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 28.0	75600	-1314.00	-99338400	130530657600	4939200
TOTAL		203400		-40866000	239016334200	35189751400

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 239016334200 + 35189751400 = 274206085600 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -40866000 / 203400 = -200.91 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 274206085600 - 203400 \times (-200.91)^2 = 265995515512 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 18 / 12) + (2700^3 \times 28 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 173890495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 18.000 / 2 + 28.000 / 2 = 2623.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2623^2) / (2 \times 2623/12 + 2512/18 + 2512/28) \\
&= 260577589682 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

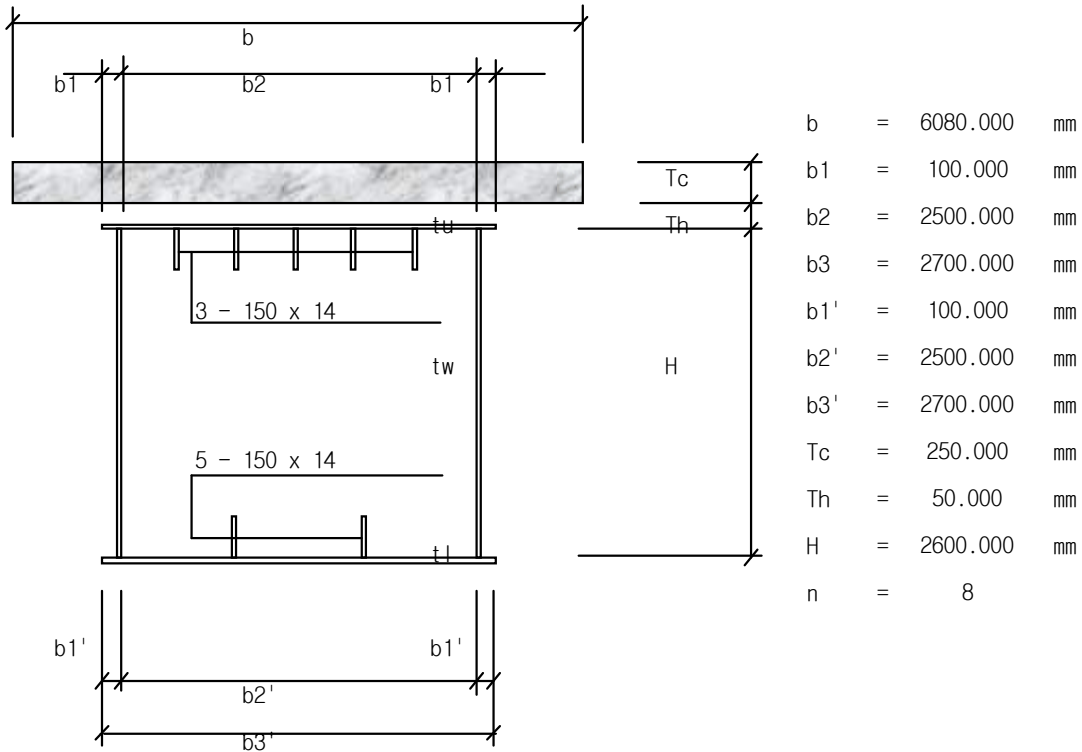
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 203400 + 1520000 / 8 = 393400 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - -200.914 + 50.000 + 250.000 / 2 = 1675.91 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1675.914 \times 203400 / 393400 = 866.50 \text{ mm} \\
dvs &= dv - dvc = 1675.914 - 866.500 = 809.41 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 265995515512 + 7916666667 / 8 + 203400 \times 809.415^2 \\
&\quad + 1520000 / 8 \times 866.500^2 = 542899194083 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 173890495200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 759191828533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 18.000 + 250.000 / 8 = 49.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2623^2) / (2 \times 2623/12 + 2512/49.25 + 2512/28) \\
&= 300506346136 \text{ mm}^4
\end{aligned}$$

- Section G1-19



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 10.0	27000	1305.00	35235000	45981675000	225000
UPPER RIB	3 - 150.0 X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL		165600		-47783400	173284202400	35186120800

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 173284202400 + 35186120800 = 208470323200 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -47783400 / 165600 = -288.55 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 208470323200 - 165600 \times (-288.547)^2 = 194682561633 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 10 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 150926995200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 10.000 / 2 + 22.000 / 2 = 2616.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2616^2) / (2 \times 2616/12 + 2512/10 + 2512/22) \\
&= 215543661400 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

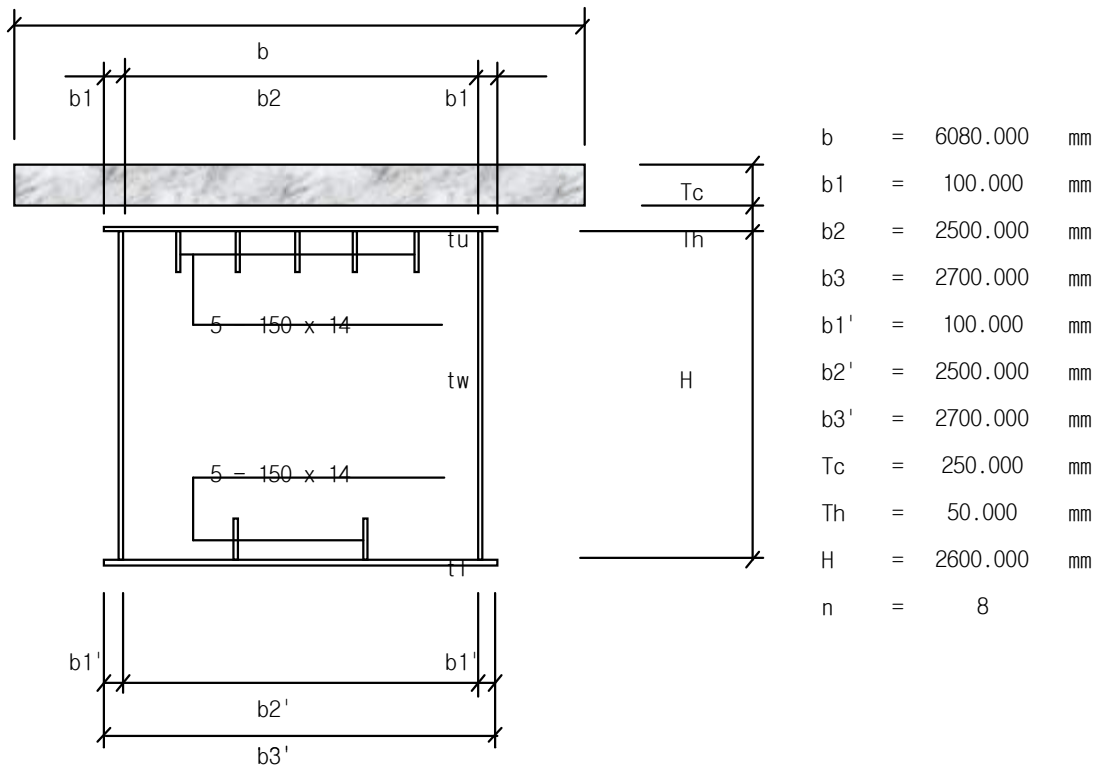
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 165600 + 1520000 / 8 = 355600 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - -288.547 + 50.000 + 250.000 / 2 = 1763.55 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1763.547 \times 165600 / 355600 = 821.27 \text{ mm} \\
dvs &= dv - dvc = 1763.547 - 821.269 = 942.28 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 194682561633 + 7916666667 / 8 + 165600 \times 942.278^2 \\
&\quad + 1520000 / 8 \times 821.269^2 = 470858127524 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 150926995200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 736228328533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 250.000 / 8 = 41.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2616^2) / (2 \times 2616/12 + 2512/41.25 + 2512/22) \\
&= 282668576781 \text{ mm}^4
\end{aligned}$$

- Section G1-20



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1306.00	-42314400	55262606400	388800
TOTAL		148200		0	142038337800	35192152600

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 142038337800 + 35192152600 = 177230490400 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= 0 / 148200 = 0.00 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 177230490400 - 148200 \times 0.00^2 = 177230490400 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 12 / 12) + (2700^3 \times 12 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 137804995200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 12.000 / 2 = 2612.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2612^2) / (2 \times 2612/12 + 2512/12 + 2512/12) \\
&= 201645129210 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

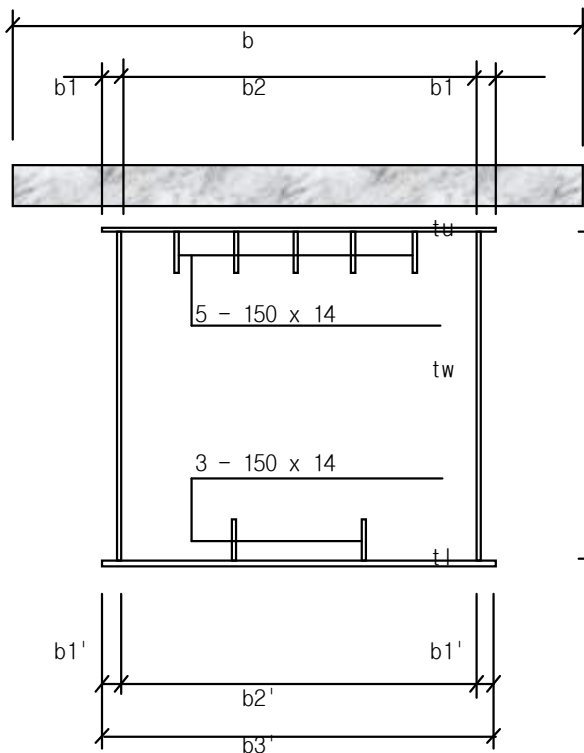
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 250.000 = 1520000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 148200 + 1520000 / 8 = 338200 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 250.000^3 / 12 = 7916666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 0.000 + 50.000 + 250.000 / 2 = 1475.00 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1475.000 \times 148200 / 338200 = 646.35 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1475.000 - 646.348 = 828.65 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 177230490400 + 7916666667 / 8 + 148200 \times 828.652^2 \\
&\quad + 1520000 / 8 \times 646.348^2 = 359359188902 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 137804995200 + 6080.000^3 \\
&\quad \times 250.000 / 12 / 8 = 723106328533 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2612^2) / (2 \times 2612/12 + 2512/43.25 + 2512/12) \\
&= 245045223097 \text{ mm}^4
\end{aligned}$$

- Section G2-1



b	=	6070.000	mm
b1	=	100.000	mm
b2	=	2500.000	mm
b3	=	2700.000	mm
b1'	=	100.000	mm
b2'	=	2500.000	mm
b3'	=	2700.000	mm
Tc	=	250.000	mm
Th	=	50.000	mm
H	=	2600.000	mm
n	=	8	

① 합성전 단면

분	규	격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
ER FL.	1	- ### X 10.0	###	###	35235000	###	225000
ER RIB	5	- 150.0 X 14.0	###	###	12862500	###	19687500
E B	2	- ### X 12.0	###				35152000000
ER RIB	3	- 150.0 X 14.0	###	###	-7717500	###	11812500
ER FL.	1	- ### X 10.0	###	###	-35235000	###	225000
TOTAL			###		5145000	###	35183950000

$$I_s' = \sum AsY^2 + \sum Io$$

$$= ### + ### = ### \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= ### / ### = ### \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= ### - ### \times ###^2 = ### \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 10 / 12) + (2700^3 \times 10 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = ### \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= ### + ### / 2 \times 2 = ### \text{ mm}$$

$$\begin{aligned}
 H_k &= H + t_u / 2 + t_l / 2 \\
 &= \text{###} + \text{###} / 2 + \text{###} / 2 = \text{###} \quad \text{mm} \\
 K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
 &= (4 \times 2512^2 \times 2610^2) / (2 \times 2610/12 + 2512/10 + 2512/10) \\
 &= \text{###} \quad \text{mm}^4
 \end{aligned}$$

② 합성후 단면

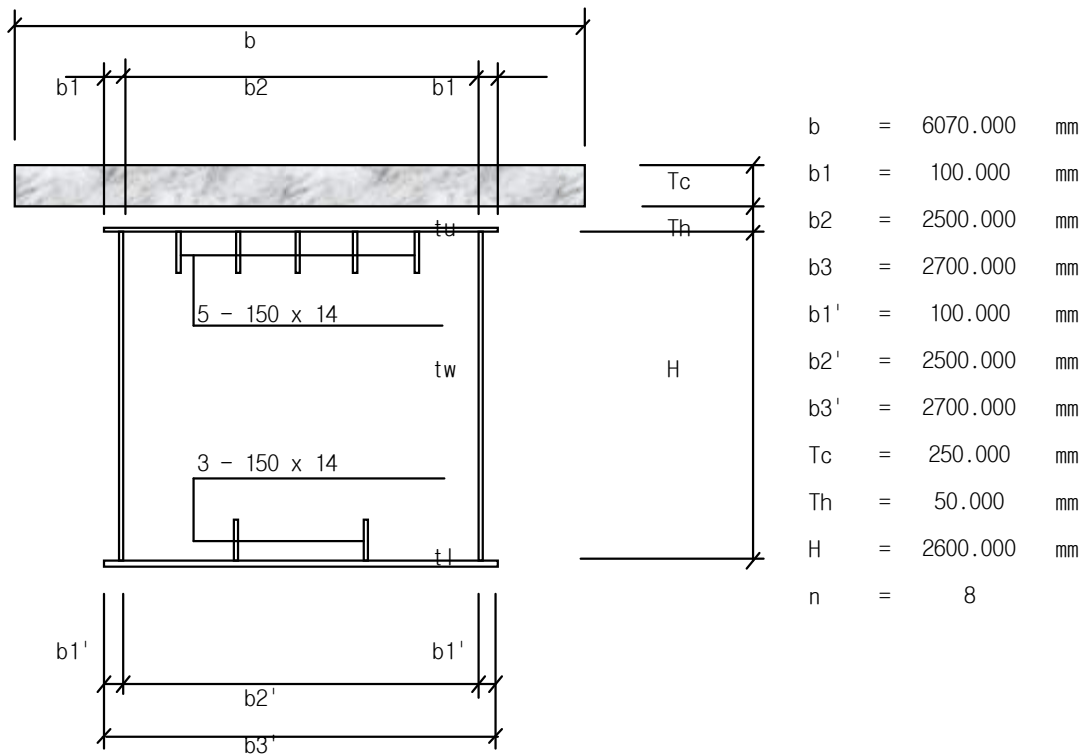
$$\begin{aligned}
 A_c &= b \times T_c \\
 &= \text{###} \times \text{###} = \text{###} \quad \text{mm}^2 \\
 A_v &= \sum A_s + A_c/N \\
 &= \text{###} + \text{###} / 8 = \text{###} \quad \text{mm}^2 \\
 I_c &= b \times T_c^3 / 12 \\
 &= \text{###} \times \text{###}^3 / 12 = \text{###} \quad \text{mm}^4 \\
 d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
 &= \text{###} / 2 - \text{###} + \text{###} + \text{###} / 2 = \text{###} \quad \text{mm} \\
 d_{vc} &= d_v \cdot \sum A_s / A_v \\
 &= \text{###} \times \text{###} / \text{###} = \text{###} \quad \text{mm} \\
 d_{vs} &= d_v - d_{vc} = \text{###} - \text{###} = \text{###} \quad \text{mm} \\
 I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
 &= \text{###} + \text{###} / 8 + \text{###} \times \text{###}^2 \\
 &\quad + \text{###} / 8 \times \text{###}^2 = \text{###} \quad \text{mm}^4 \\
 I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
 &= \text{###} + \text{###}^3 \\
 &\quad \times \text{###} / 12 / 8 = \text{###} \quad \text{mm}^4
 \end{aligned}$$

- 비틀림 강성

★ 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
 t_{cu} &= t_u + T_c / N \\
 &= \text{###} + \text{###} / 8 = \text{###} \quad \text{mm} \\
 K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
 &= (4 \times 2512^2 \times 2610^2) / (2 \times 2610/12 + 2512/41.25 + 2512/10) \\
 &= \text{###} \quad \text{mm}^4
 \end{aligned}$$

- Section G2-2



① 합성전 단면

구 분	규 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1 - 2700.0 X 10.0	27000	-1305.00	-35235000	45981675000	225000
TOTAL		138600		12224400	126454781400	35184113800

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 126454781400 + 35184113800 = 161638895200 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= 12224400 / 138600 = 88.20 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 161638895200 - 138600 \times 88.199^2 = 160560713704 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 12 / 12) + (2700^3 \times 10 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 134524495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 10.000 / 2 = 2611.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2611^2) / (2 \times 2611/12 + 2512/12 + 2512/10) \\
&= 192110202989 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

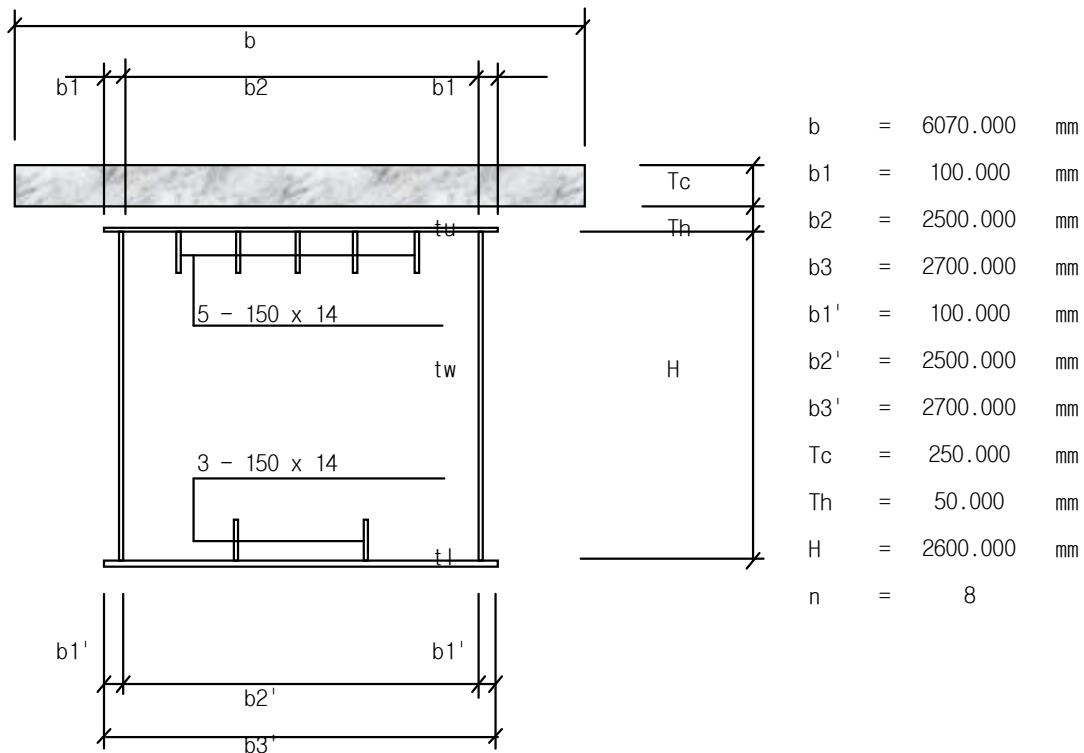
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c / N \\
&= 138600 + 1517500 / 8 = 328288 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 88.199 + 50.000 + 250.000 / 2 = 1386.80 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1386.801 \times 138600 / 328288 = 585.49 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1386.801 - 585.495 = 801.31 \text{ mm} \\
I_{v33} &= I_{33} + I_c / N + \sum A_s \cdot d_{vs}^2 + A_c / N \cdot d_{vc}^2 \\
&= 160560713704 + 7903645833 / 8 + 138600 \times 801.306^2 \\
&\quad + 1517500 / 8 \times 585.495^2 = 315568203267 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 134524495200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 716942575929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2611^2) / (2 \times 2611/12 + 2512/43.25 + 2512/10) \\
&= 231142004859 \text{ mm}^4
\end{aligned}$$

- Section G2-3



① 합성전 단면

구 분	규 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1307.00	-49404600	64571812200	617400
TOTAL		149400		-1945200	145044918600	35184506200

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 145044918600 + 35184506200 = 180229424800 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -1945200 / 149400 = -13.02 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 180229424800 - 149400 \times (-13.02)^2 = 180204098140 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 12 / 12) + (2700^3 \times 14 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 141085495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 14.000 / 2 = 2613.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2613^2) / (2 \times 2613/12 + 2512/12 + 2512/14) \\
&= 209080173861 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

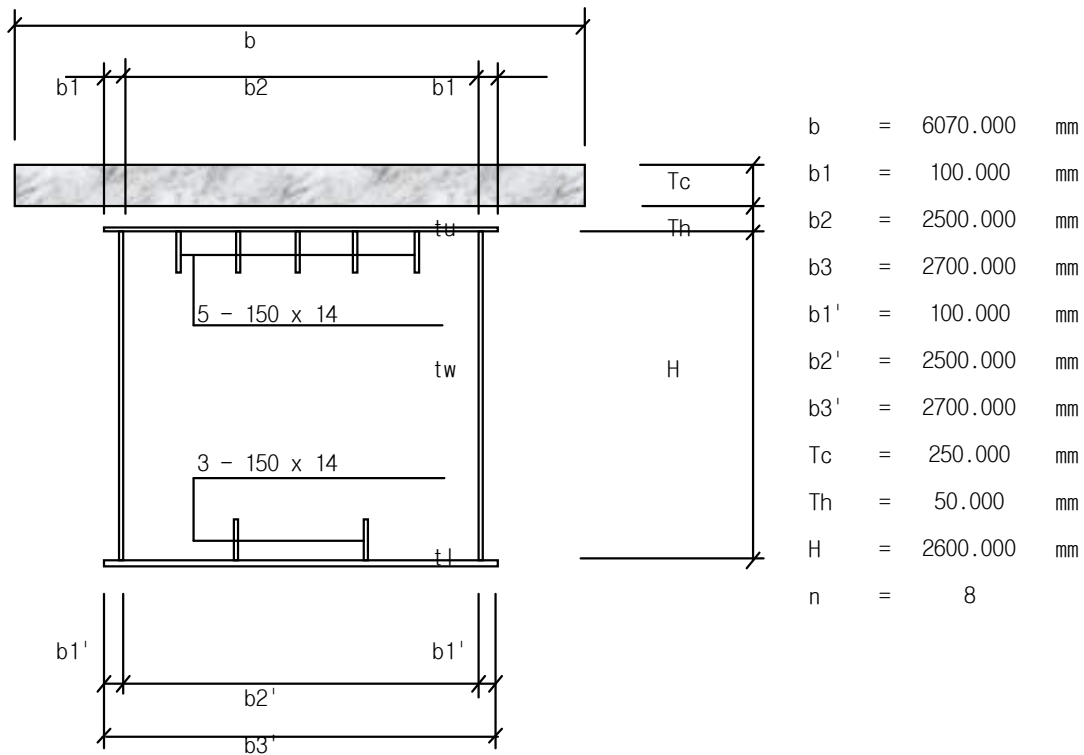
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 149400 + 1517500 / 8 = 339088 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 13.020 + 50.000 + 250.000 / 2 = 1488.02 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1488.020 \times 149400 / 339088 = 655.61 \text{ mm} \\
dvs &= dv - dvc = 1488.020 - 655.613 = 832.41 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 180204098140 + 7903645833 / 8 + 149400 \times 832.407^2 \\
&\quad + 1517500 / 8 \times 655.613^2 = 366244620765 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 141085495200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 723503575929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2613^2) / (2 \times 2613/12 + 2512/43.25 + 2512/14) \\
&= 256068931132 \text{ mm}^4
\end{aligned}$$

- Section G2-4



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 10.0	52000				29293333333
LOWER RIB	3 - 150.0 X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1307.00	-49404600	64571812200	617400
TOTAL		139000		-1945200	145044918600	29325839533

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 145044918600 + 29325839533 = 174370758133 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -1945200 / 139000 = -13.99 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 174370758133 - 139000 \times (-13.99)^2 = 174343536529 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 12 / 12) + (2700^3 \times 14 / 12) + ((2600 \times 10^3 / 12) + (2600 \times 10 \times (2500 / 2 + 10 / 2)^2)) \times 2$$

$$= 12454823333 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 10.000 / 2 \times 2 = 2510.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 14.000 / 2 = 2613.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2510^2 \times 2613^2) / (2 \times 2613/10 + 2510/12 + 2510/14) \\
&= 188861270224 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

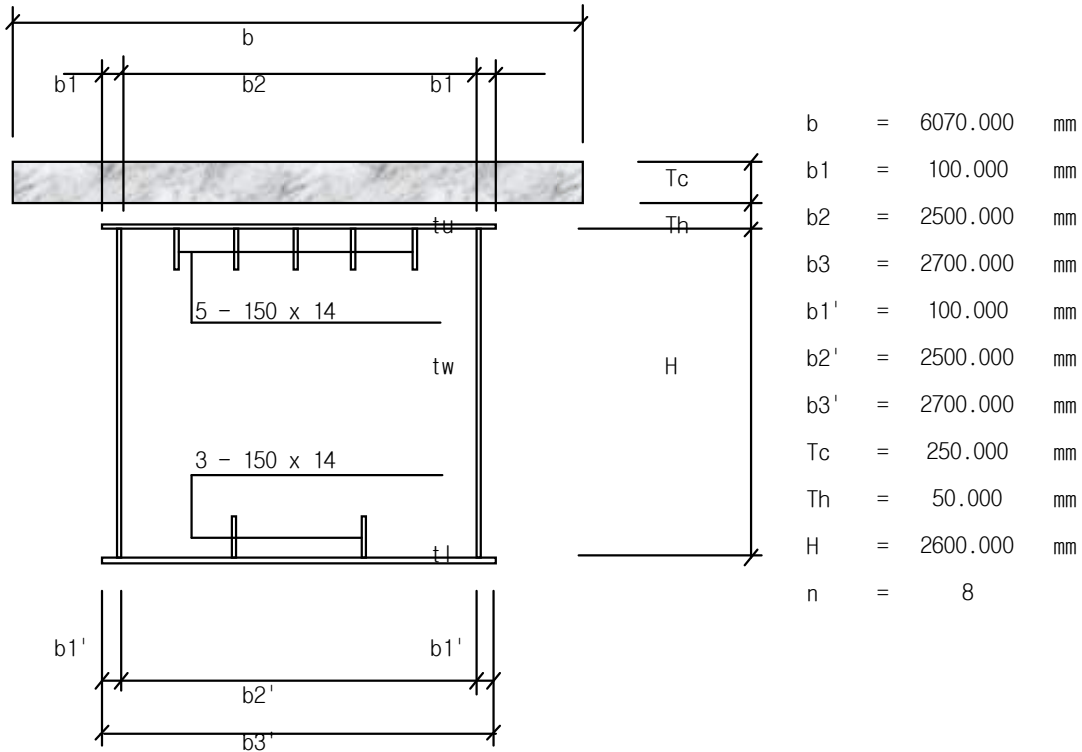
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 139000 + 1517500 / 8 = 328688 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 13.994 + 50.000 + 250.000 / 2 = 1488.99 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1488.994 \times 139000 / 328688 = 629.69 \text{ mm} \\
dvs &= dv - dvc = 1488.994 - 629.687 = 859.31 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 174343536529 + 7903645833 / 8 + 139000 \times 859.307^2 \\
&\quad + 1517500 / 8 \times 629.687^2 = 353182513383 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 124548233333 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 706966314063 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2510^2 \times 2613^2) / (2 \times 2613/10 + 2510/43.25 + 2510/14) \\
&= 226421755134 \text{ mm}^4
\end{aligned}$$

- Section G2-5



① 합성전 단면

구 분	규 격				As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	lo(mm ⁴)
UPPER FL.	1	-	2700.0	X 16.0	43200	1308.00	56505600	73909324800	921600
UPPER RIB	5	-	150.0	X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2	-	2600.0	X 10.0	52000				29293333333
LOWER RIB	3	-	150.0	X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1	-	2700.0	X 14.0	37800	-1307.00	-49404600	64571812200	617400
TOTAL					149800		12246000	163691637000	29326372333

$$I_s = \sum A s Y^2 + \sum I_0$$

$$= 163691637000 + 29326372333 = 193018009333 \text{ mm}^4$$

$$\delta s = \frac{\sum A_s Y}{\sum A_s} = \frac{12246000}{149800} = 81.75 \text{ mm}$$

$$I_{33} = I_{s'} - \sum A_s \times \delta s^2$$

$$= 193018009333 - 149800 \times 81.749^2 = 192016911096 \text{ mm}^4$$

$$\begin{aligned}
 I_{22} &= (b3^3 \times t_u / 12) + (b3^{13} \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b2 / 2 + t_w / 2)^2)) \times 2 \\
 &= (2700^3 \times 16 / 12) + (2700^3 \times 14 / 12) + ((2600 \times 10^3 / 12) \\
 &\quad + (2600 \times 10 \times (2500 / 2 + 10 / 2)^2)) \times 2 = 131109233333 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2 = 2500.000 + 10.000 / 2 \times 2 = 2510.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 16.000 / 2 + 14.000 / 2 = 2615.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2510^2 \times 2615^2) / (2 \times 2615/10 + 2510/16 + 2510/14) \\
&= 200574819617 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

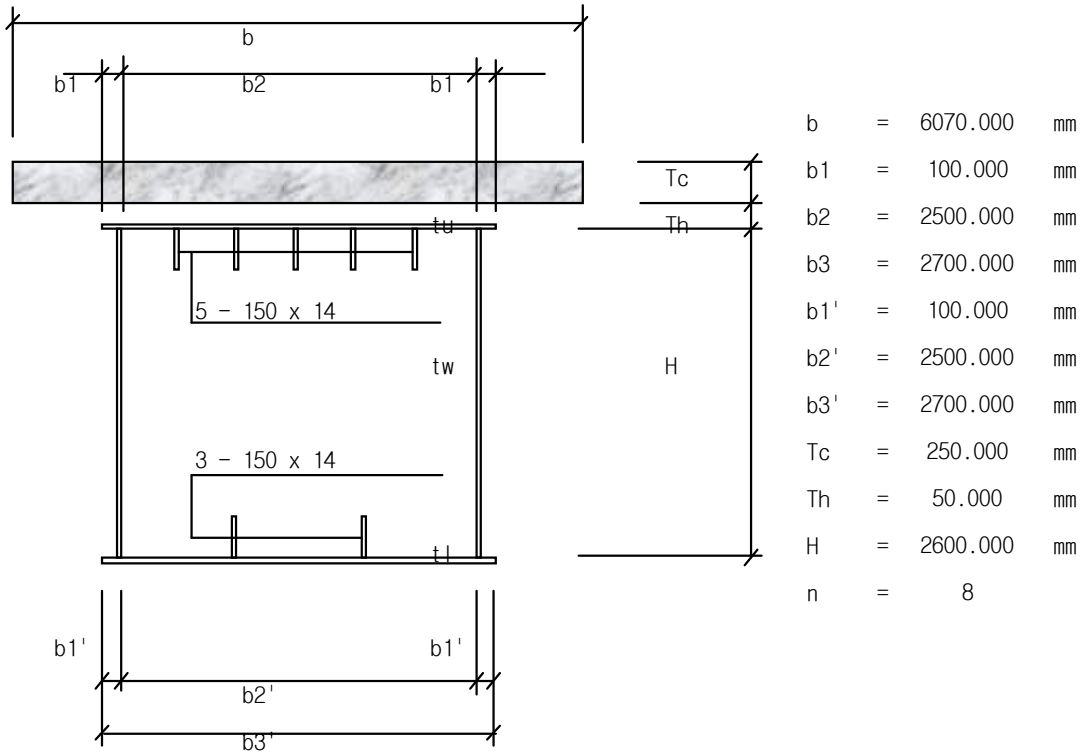
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 149800 + 1517500 / 8 = 339488 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 81.749 + 50.000 + 250.000 / 2 = 1393.25 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1393.251 \times 149800 / 339488 = 614.78 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1393.251 - 614.777 = 778.47 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 192016911096 + 7903645833 / 8 + 149800 \times 778.474^2 \\
&\quad + 1517500 / 8 \times 614.777^2 = 355479462820 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 131109233333 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 713527314063 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 16.000 + 250.000 / 8 = 47.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2510^2 \times 2615^2) / (2 \times 2615/10 + 2510/47.25 + 2510/14) \\
&= 228123266465 \text{ mm}^4
\end{aligned}$$

- Section G2-6



① 합성전 단면

구 분	규 격					As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	lo(mm ⁴)
UPPER FL.	1	-	2700.0	X	16.0	43200	1308.00	56505600	73909324800	921600
UPPER RIB	5	-	150.0	X	14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2	-	2600.0	X	10.0	52000				29293333333
LOWER RIB	3	-	150.0	X	14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1	-	2700.0	X	22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL						171400		-16222800	201211852200	29328150733

$$|s'| = \sum A s Y^2 + \sum l o$$

$$= 201211852200 + 29328150733 = 230540002933 \text{ mm}^4$$

$$\delta_s = \frac{\sum AsY}{\sum As} = \frac{-16222800}{171400} = -94.65 \text{ mm}$$

$$I_{33} = I_{S'} - \sum A_S \times \delta S^2$$

$$= 230540002933 - 171400 \times (-94.649)^2 = 229004534790 \text{ mm}^4$$

$$\begin{aligned}
 I_{22} &= (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2 \\
 &= (2700^3 \times 16 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 10^3 / 12) \\
 &\quad + (2600 \times 10 \times (2500 / 2 + 10 / 2)^2)) \times 2 = 144231233333 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 10.000 / 2 \times 2 = 2510.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 16.000 / 2 + 22.000 / 2 = 2619.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2510^2 \times 2619^2) / (2 \times 2619/10 + 2510/16 + 2510/22) \\
&= 217489953818 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

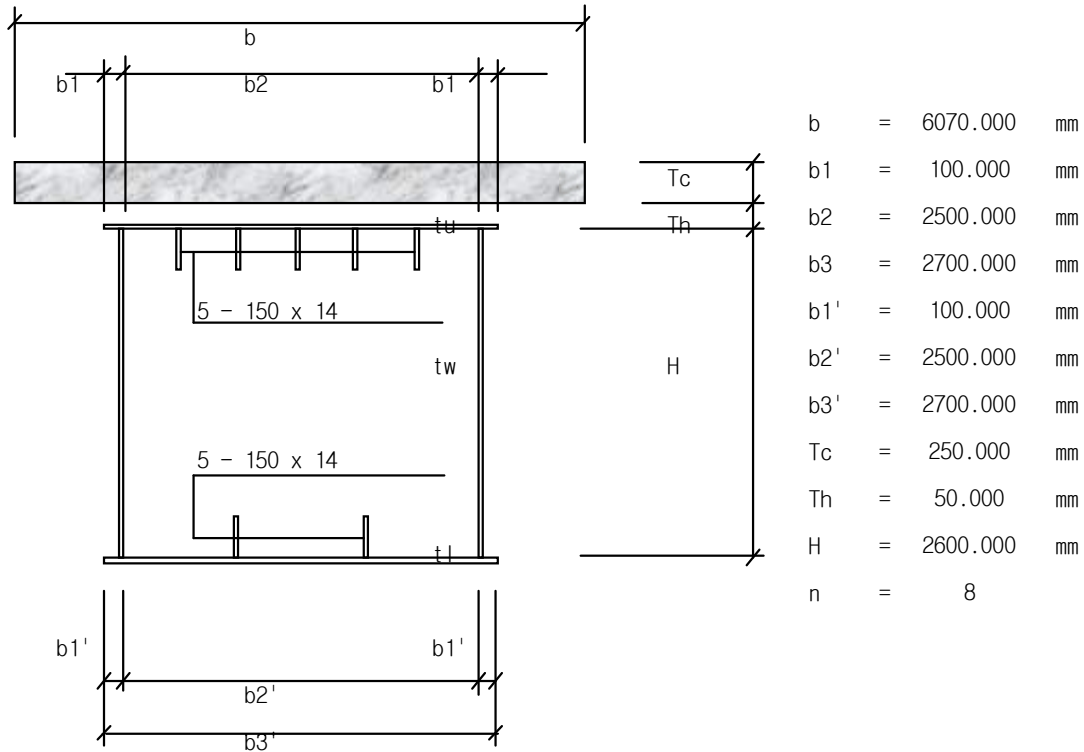
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 171400 + 1517500 / 8 = 361088 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 94.649 + 50.000 + 250.000 / 2 = 1569.65 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1569.649 \times 171400 / 361088 = 745.08 \text{ mm} \\
dvs &= dv - dvc = 1569.649 - 745.076 = 824.57 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 229004534790 + 7903645833 / 8 + 171400 \times 824.572^2 \\
&\quad + 1517500 / 8 \times 745.076^2 = 451833609238 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 144231233333 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 726649314063 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 16.000 + 250.000 / 8 = 47.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2510^2 \times 2619^2) / (2 \times 2619/10 + 2510/47.25 + 2510/22) \\
&= 250145366830 \text{ mm}^4
\end{aligned}$$

- Section G2-7



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 16.0	43200	1308.00	56505600	73909324800	921600
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL		186000		-21367800	207514477200	35194692400

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 207514477200 + 35194692400 = 242709169600 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -21367800 / 186000 = -114.88 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 242709169600 - 186000 \times (-114.88)^2 = 240254422950 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 16 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 160768495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 16.000 / 2 + 22.000 / 2 = 2619.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2619^2) / (2 \times 2619/12 + 2512/16 + 2512/22) \\
&= 244642677074 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

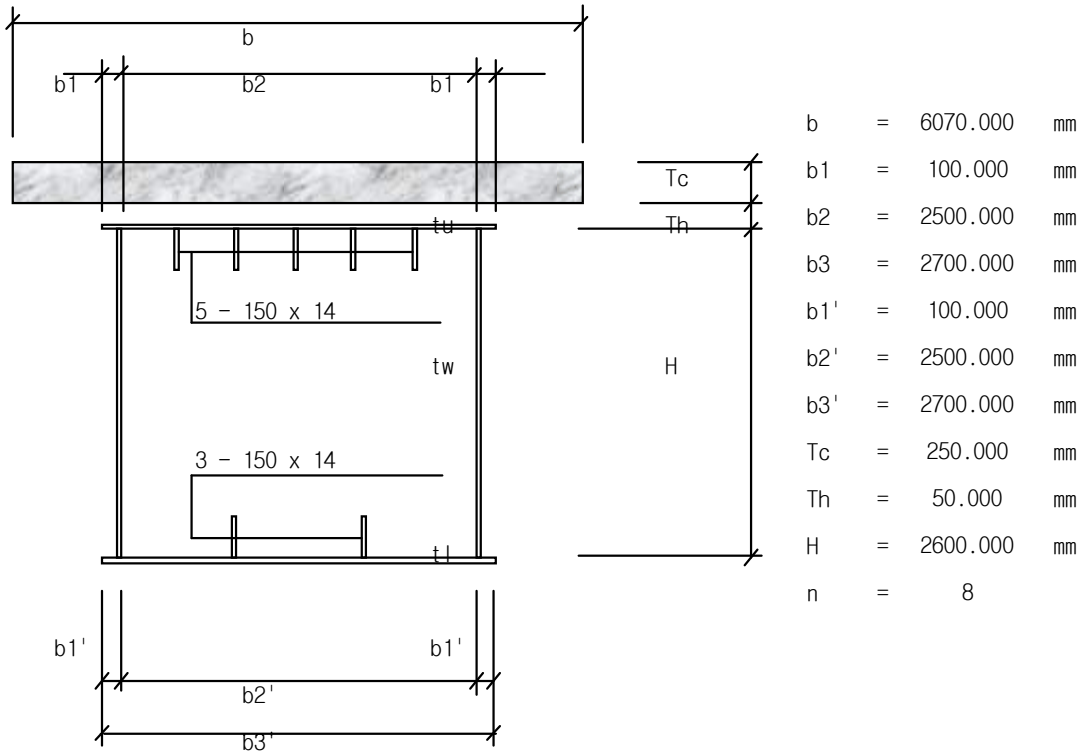
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 186000 + 1517500 / 8 = 375688 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - -114.881 + 50.000 + 250.000 / 2 = 1589.88 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1589.881 \times 186000 / 375688 = 787.14 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1589.881 - 787.138 = 802.74 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 240254422950 + 7903645833 / 8 + 186000 \times 802.743^2 \\
&\quad + 1517500 / 8 \times 787.138^2 = 478627752192 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 160768495200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 743186575929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 16.000 + 250.000 / 8 = 47.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2619^2) / (2 \times 2619/12 + 2512/47.25 + 2512/22) \\
&= 286710884196 \text{ mm}^4
\end{aligned}$$

- Section G2-8



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL		171000		-30414000	182565133800	35186284600

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 182565133800 + 35186284600 = 217751418400 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -30414000 / 171000 = -177.86 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 217751418400 - 171000 \times (-177.86)^2 = 212341995032 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 12 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 154207495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 22.000 / 2 = 2617.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2617^2) / (2 \times 2617/12 + 2512/12 + 2512/22) \\
&= 227549022588 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

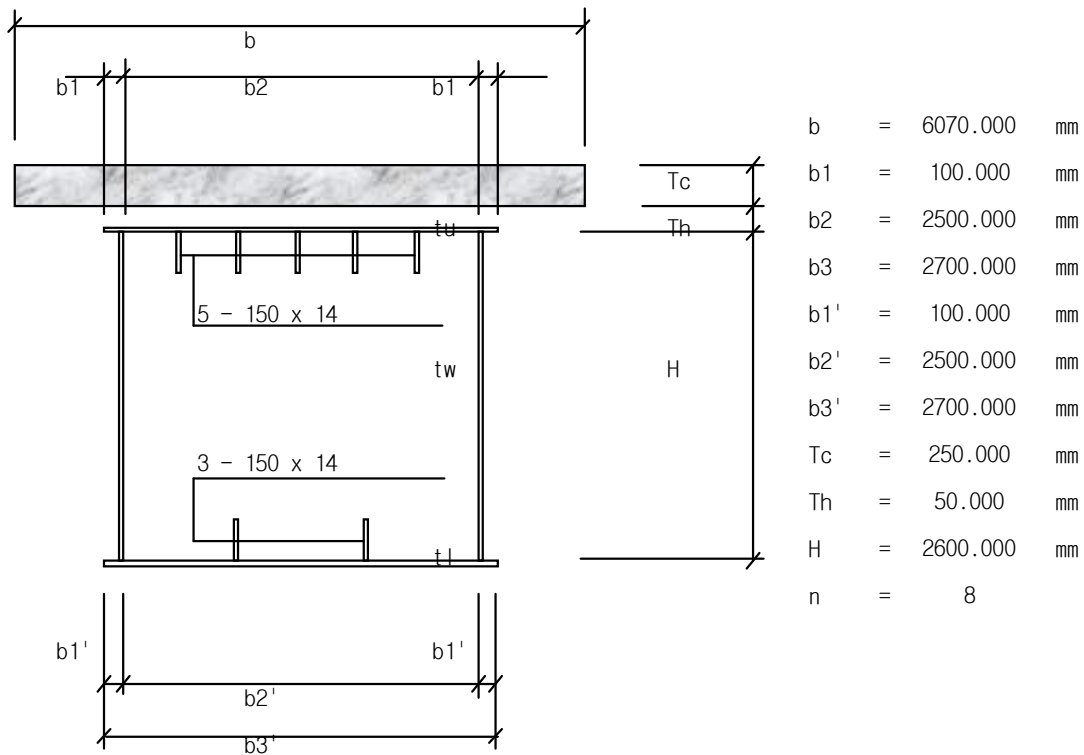
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 171000 + 1517500 / 8 = 360688 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 177.860 + 50.000 + 250.000 / 2 = 1652.86 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1652.860 \times 171000 / 360688 = 783.61 \text{ mm} \\
dvs &= dv - dvc = 1652.860 - 783.612 = 869.25 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 212341995032 + 7903645833 / 8 + 171000 \times 869.248^2 \\
&\quad + 1517500 / 8 \times 783.612^2 = 459013278788 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 154207495200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 736625575929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2617^2) / (2 \times 2617/12 + 2512/43.25 + 2512/22) \\
&= 284116534224 \text{ mm}^4
\end{aligned}$$

- Section G2-9



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1225.00	-7717500	9453937500	11812500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1307.00	-49404600	64571812200	617400
TOTAL		149400		-1945200	145044918600	35184506200

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 145044918600 + 35184506200 = 180229424800 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -1945200 / 149400 = -13.02 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 180229424800 - 149400 \times (-13.02)^2 = 180204098140 \text{ mm}^4$$

$$I_{22} = (b3^3 \times tu / 12) + (b3'^3 \times tl / 12) + ((H \times tw^3 / 12) + (H \times tw \times (b2 / 2 + tw / 2)^2)) \times 2$$

$$= (2700^3 \times 12 / 12) + (2700^3 \times 14 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 141085495200 \text{ mm}^4$$

- 비틀림 강성

$$bk = b2 + tw / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 14.000 / 2 = 2613.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2613^2) / (2 \times 2613/12 + 2512/12 + 2512/14) \\
&= 209080173861 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

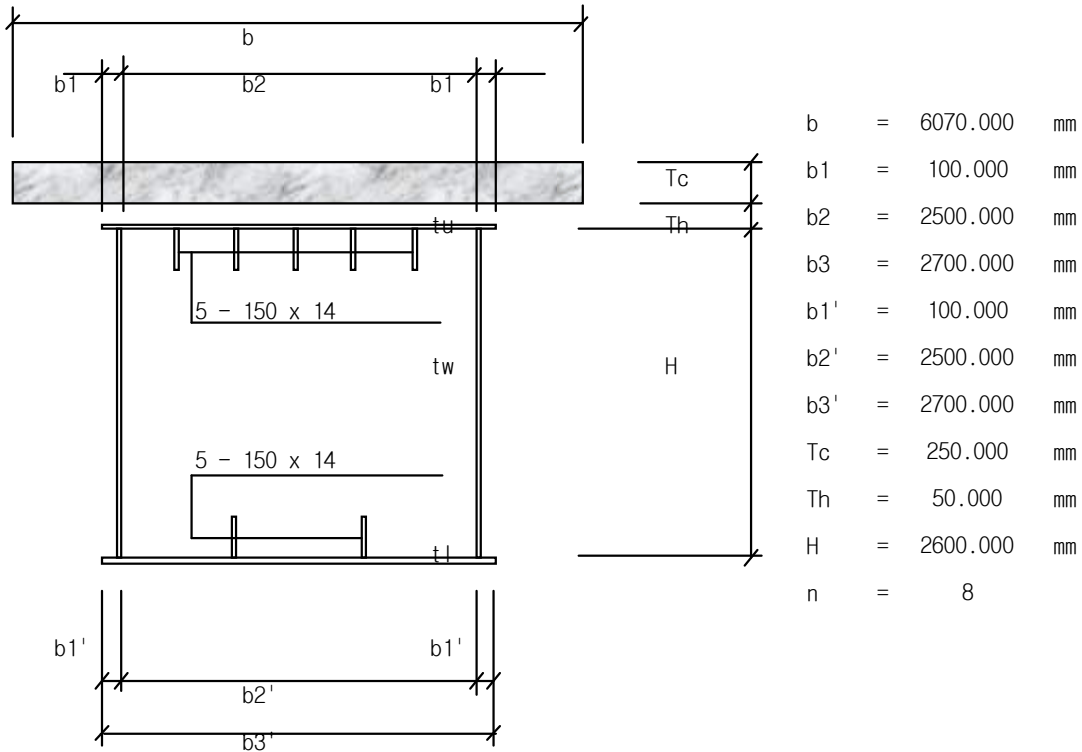
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 149400 + 1517500 / 8 = 339088 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 13.020 + 50.000 + 250.000 / 2 = 1488.02 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1488.020 \times 149400 / 339088 = 655.61 \text{ mm} \\
dvs &= dv - dvc = 1488.020 - 655.613 = 832.41 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 180204098140 + 7903645833 / 8 + 149400 \times 832.407^2 \\
&\quad + 1517500 / 8 \times 655.613^2 = 366244620765 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 141085495200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 723503575929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2613^2) / (2 \times 2613/12 + 2512/43.25 + 2512/14) \\
&= 256068931132 \text{ mm}^4
\end{aligned}$$

- Section G2-10



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 10.0	27000	1305.00	35235000	45981675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1307.00	-49404600	64571812200	617400
TOTAL		148200		-14169600	142066612200	35192217400

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 142066612200 + 35192217400 = 177258829600 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -14169600 / 148200 = -95.61 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 177258829600 - 148200 \times (-95.61)^2 = 175904055213 \text{ mm}^4$$

$$I_{22} = (b3^3 \times tu / 12) + (b3'^3 \times tl / 12) + ((H \times tw^3 / 12) + (H \times tw \times (b2 / 2 + tw / 2)^2)) \times 2$$

$$= (2700^3 \times 10 / 12) + (2700^3 \times 14 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 137804995200 \text{ mm}^4$$

- 비틀림 강성

$$bk = b2 + tw / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 10.000 / 2 + 14.000 / 2 = 2612.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2612^2) / (2 \times 2612/12 + 2512/10 + 2512/14) \\
&= 198859718191 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

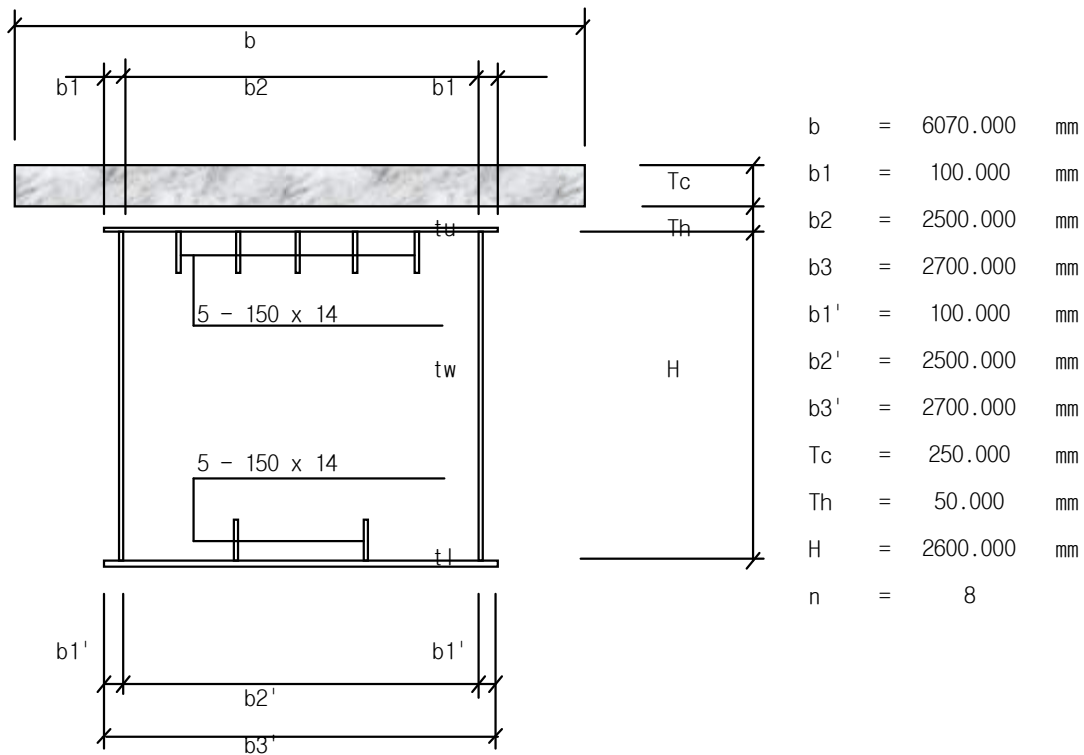
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 148200 + 1517500 / 8 = 337888 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 95.611 + 50.000 + 250.000 / 2 = 1570.61 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1570.611 \times 148200 / 337888 = 688.88 \text{ mm} \\
dvs &= dv - dvc = 1570.611 - 688.882 = 881.73 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 175904055213 + 7903645833 / 8 + 148200 \times 881.729^2 \\
&\quad + 1517500 / 8 \times 688.882^2 = 382127398708 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 137804995200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 720223075929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 250.000 / 8 = 41.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2612^2) / (2 \times 2612/12 + 2512/41.25 + 2512/14) \\
&= 254869649249 \text{ mm}^4
\end{aligned}$$

- Section G2-11



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 10.0	27000	1305.00	35235000	45981675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1306.00	-42314400	55262606400	388800
TOTAL		142800		-7079400	132757406400	35191988800

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 132757406400 + 35191988800 = 167949395200 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -7079400 / 142800 = -49.58 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 167949395200 - 142800 \times (-49.576)^2 = 167598429483 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 10 / 12) + (2700^3 \times 12 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 134524495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 10.000 / 2 + 12.000 / 2 = 2611.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2611^2) / (2 \times 2611/12 + 2512/10 + 2512/12) \\
&= 192110202989 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

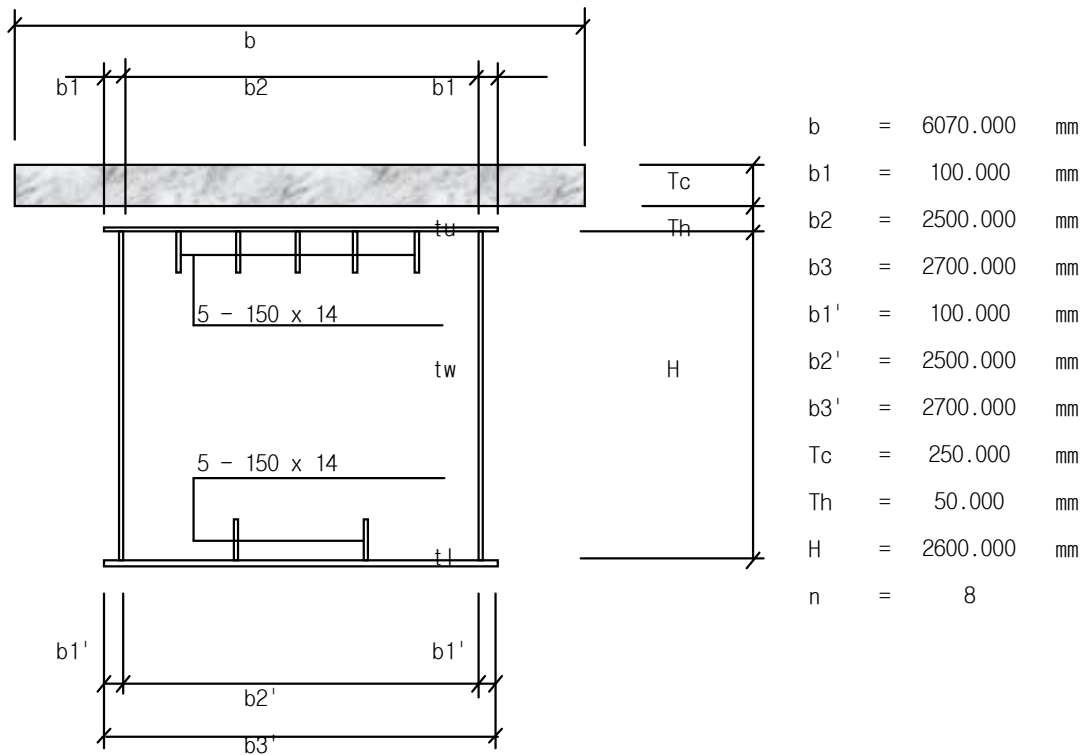
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 142800 + 1517500 / 8 = 332488 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 49.576 + 50.000 + 250.000 / 2 = 1524.58 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1524.576 \times 142800 / 332488 = 654.79 \text{ mm} \\
dvs &= dv - dvc = 1524.576 - 654.790 = 869.79 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 167598429483 + 7903645833 / 8 + 142800 \times 869.786^2 \\
&\quad + 1517500 / 8 \times 654.790^2 = 357946951916 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 134524495200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 716942575929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 250.000 / 8 = 41.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2611^2) / (2 \times 2611/12 + 2512/41.25 + 2512/12) \\
&= 243937975649 \text{ mm}^4
\end{aligned}$$

- Section G2-12



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 18.0	48600	1309.00	63617400	83275176600	1312200
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1306.00	-42314400	55262606400	388800
TOTAL		164400		21303000	170050908000	35193076000

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 170050908000 + 35193076000 = 205243984000 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= 21303000 / 164400 = 129.58 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 205243984000 - 164400 \times 129.58^2 = 202483535040 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 18 / 12) + (2700^3 \times 12 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 147646495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 18.000 / 2 + 12.000 / 2 = 2615.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2615^2) / (2 \times 2615/12 + 2512/18 + 2512/12) \\
&= 219951382706 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

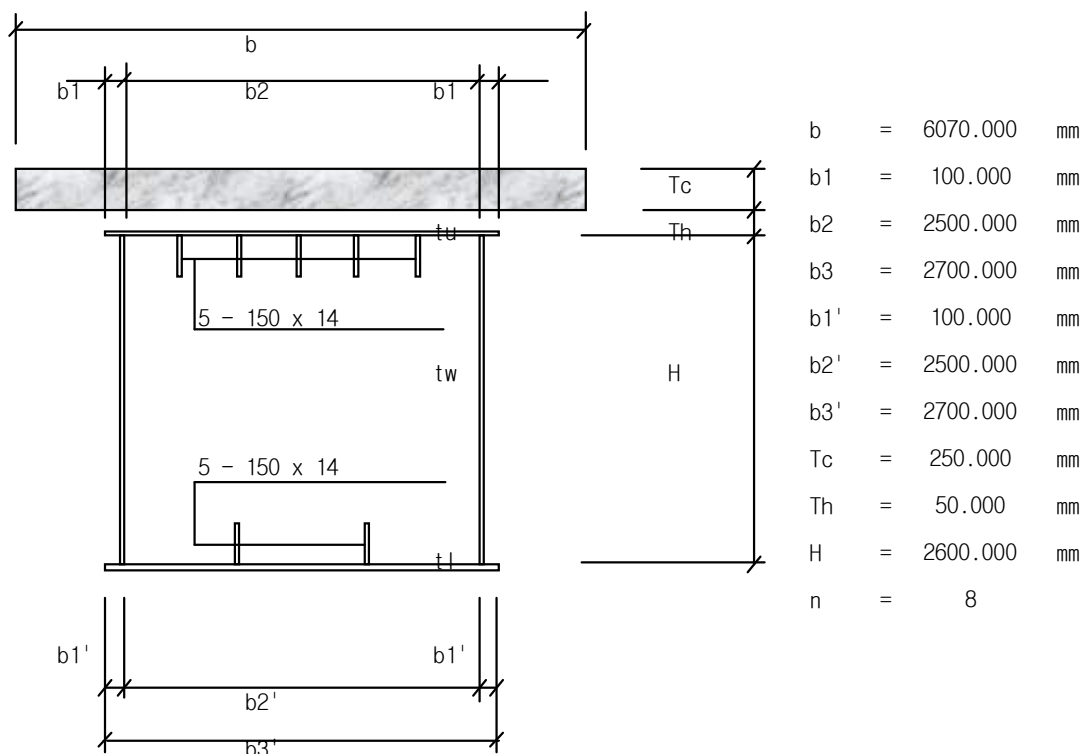
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 164400 + 1517500 / 8 = 354088 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 129.580 + 50.000 + 250.000 / 2 = 1345.42 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1345.420 \times 164400 / 354088 = 624.67 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1345.420 - 624.668 = 720.75 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 202483535040 + 7903645833 / 8 + 164400 \times 720.752^2 \\
&\quad + 1517500 / 8 \times 624.668^2 = 362892480301 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 147646495200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 730064575929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 18.000 + 250.000 / 8 = 49.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2615^2) / (2 \times 2615/12 + 2512/49.25 + 2512/12) \\
&= 247928387787 \text{ mm}^4
\end{aligned}$$

- Section G2-13



① 합성전 단면

구 분	규 격				As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	lo(mm ⁴)
UPPER FL.	1	-	2700.0	X 18.0	48600	1309.00	63617400	83275176600	1312200
UPPER RIB	5	-	150.0	X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2	-	2600.0	X 12.0	62400				35152000000
LOWER RIB	5	-	150.0	X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1	-	2700.0	X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL					191400		-14256000	216880329000	35195083000

$$I_s' = \sum A s Y^2 + \sum I_o$$

$$= 216880329000 + 35195083000 = 252075412000 \text{ mm}^4$$

$$\delta s = \frac{\sum AsY}{\sum As} = \frac{-14256000}{191400} = -74.48 \text{ mm}$$

$$I_{33} = I_{s'} - \sum A_s \times \delta s^2$$

$$= 252075412000 - 191400 \times -74.483^2 = 251013585793 \text{ mm}^4$$

$$\begin{aligned}
 I_{22} &= (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2 \\
 &= (2700^3 \times 18 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) \\
 &\quad + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 164048995200 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 18.000 / 2 + 22.000 / 2 = 2620.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2620^2) / (2 \times 2620/12 + 2512/18 + 2512/22) \\
&= 250956541032 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

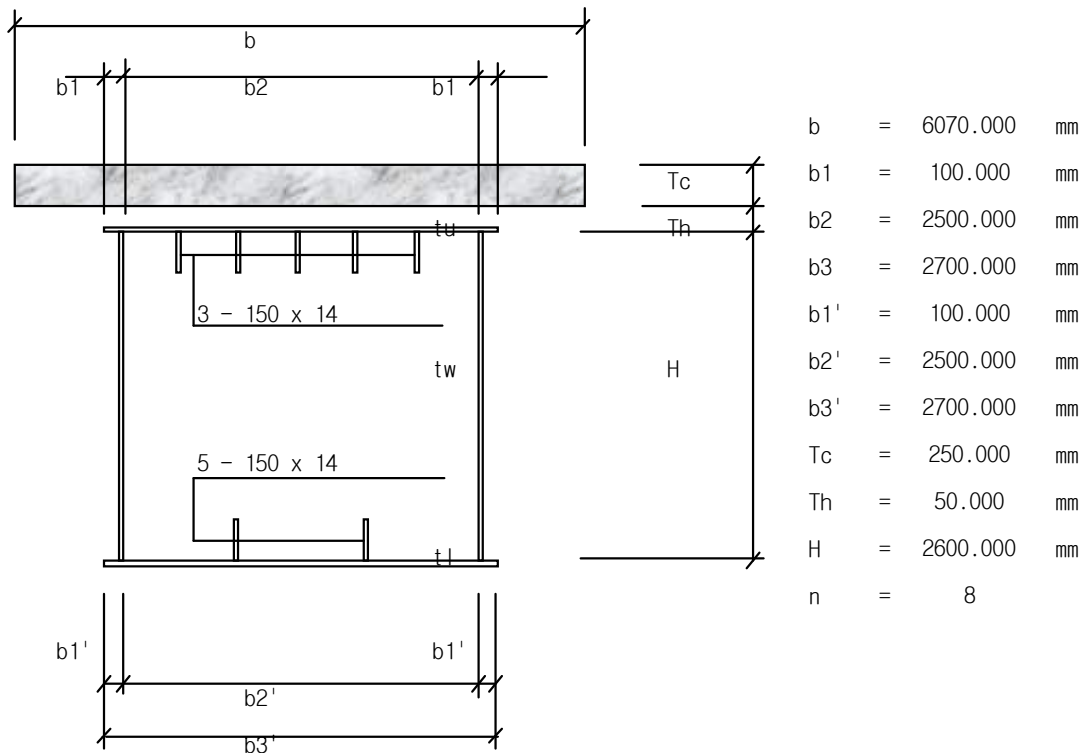
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 191400 + 1517500 / 8 = 381088 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 74.483 + 50.000 + 250.000 / 2 = 1549.48 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1549.483 \times 191400 / 381088 = 778.22 \text{ mm} \\
dvs &= dv - dvc = 1549.483 - 778.223 = 771.26 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 251013585793 + 7903645833 / 8 + 191400 \times 771.260^2 \\
&\quad + 1517500 / 8 \times 778.223^2 = 480734864154 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 164048995200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 746467075929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 18.000 + 250.000 / 8 = 49.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2620^2) / (2 \times 2620/12 + 2512/49.25 + 2512/22) \\
&= 287879678919 \text{ mm}^4
\end{aligned}$$

- Section G2-14



① 합성전 단면

구 분	규 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 18.0	48600	1309.00	63617400	83275176600	1312200
UPPER RIB	3 - 150.0 X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL		187200		-19401000	210577704000	35187208000

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 210577704000 + 35187208000 = 245764912000 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -19401000 / 187200 = -103.64 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 245764912000 - 187200 \times (-103.638)^2 = 243754234644 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 18 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 164048995200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 18.000 / 2 + 22.000 / 2 = 2620.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2620^2) / (2 \times 2620/12 + 2512/18 + 2512/22) \\
&= 250956541032 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

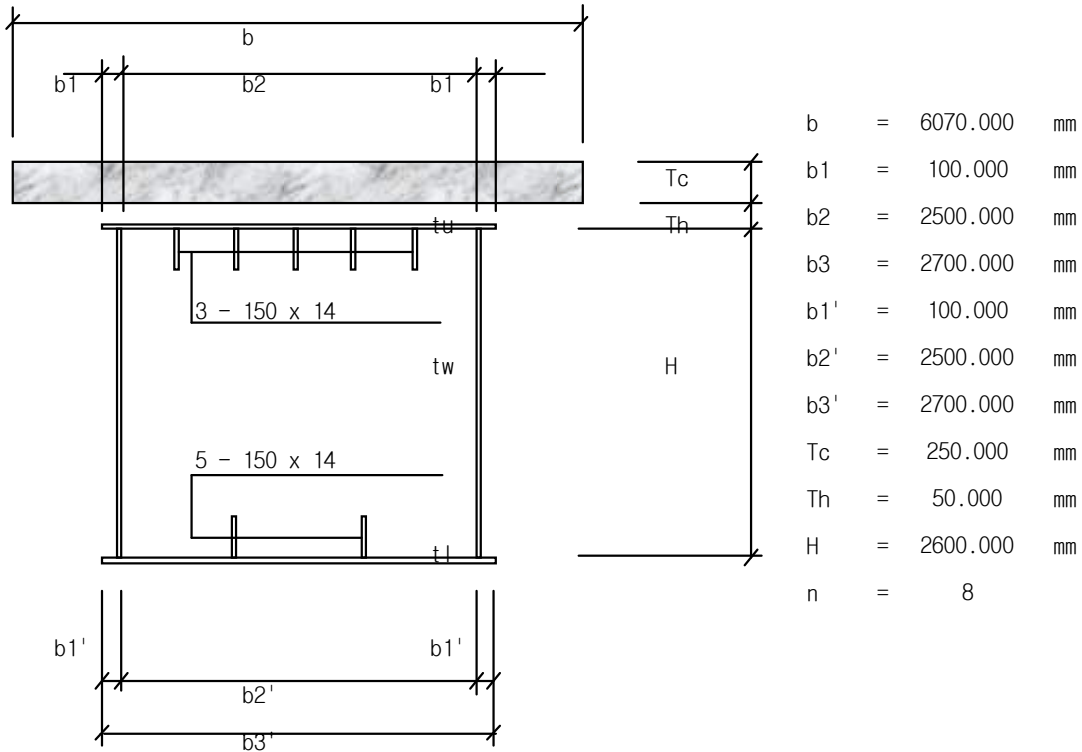
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 187200 + 1517500 / 8 = 376888 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 103.638 + 50.000 + 250.000 / 2 = 1578.64 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1578.638 \times 187200 / 376888 = 784.11 \text{ mm} \\
dvs &= dv - dvc = 1578.638 - 784.109 = 794.53 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 243754234644 + 7903645833 / 8 + 187200 \times 794.529^2 \\
&\quad + 1517500 / 8 \times 784.109^2 = 479542048425 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 164048995200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 746467075929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 18.000 + 250.000 / 8 = 49.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2620^2) / (2 \times 2620/12 + 2512/49.25 + 2512/22) \\
&= 287879678919 \text{ mm}^4
\end{aligned}$$

- Section G2-15



① 합성전 단면

구 분	규 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 28.0	75600	1314.00	99338400	130530657600	4939200
UPPER RIB	3 - 150.0 X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL		214200		16320000	257833185000	35190835000

$$I_s' = \sum AsY^2 + \sum Io$$

$$= 257833185000 + 35190835000 = 293024020000 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= 16320000 / 214200 = 76.19 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 293024020000 - 214200 \times 76.19^2 = 291780591429 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 28 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 180451495200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 28.000 / 2 + 22.000 / 2 = 2625.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2625^2) / (2 \times 2625/12 + 2512/28 + 2512/22) \\
&= 271163705148 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

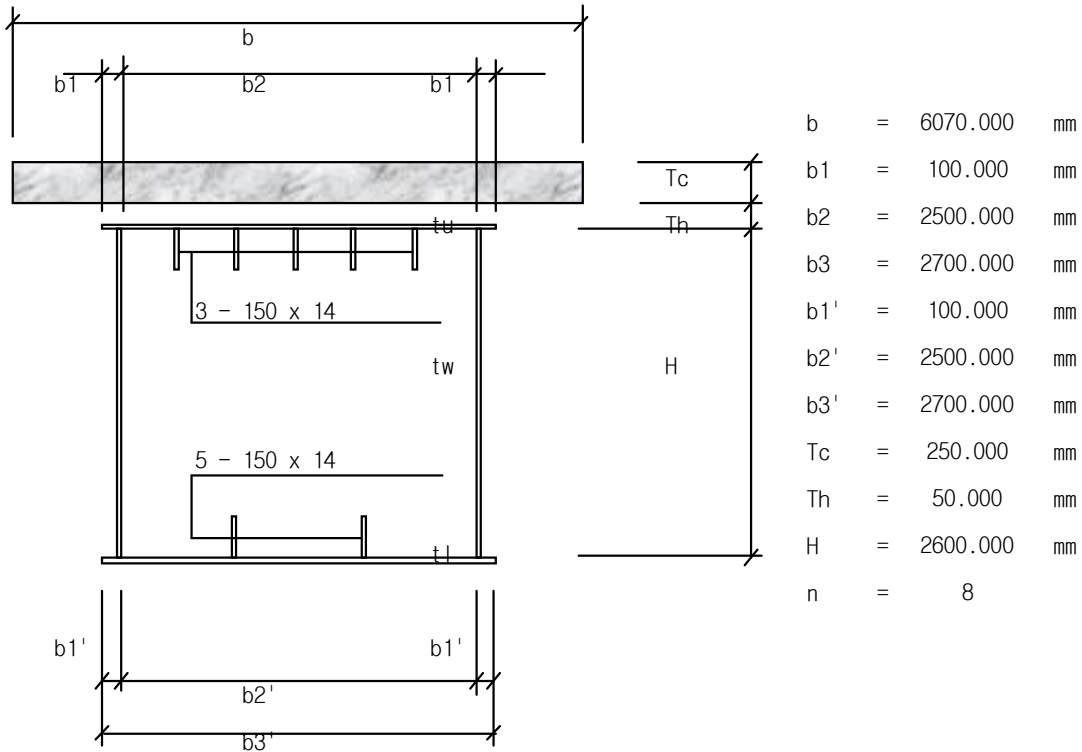
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 214200 + 1517500 / 8 = 403888 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 76.190 + 50.000 + 250.000 / 2 = 1398.81 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1398.810 \times 214200 / 403888 = 741.85 \text{ mm} \\
dvs &= dv - dvc = 1398.810 - 741.853 = 656.96 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 291780591429 + 7903645833 / 8 + 214200 \times 656.957^2 \\
&\quad + 1517500 / 8 \times 741.853^2 = 489609259506 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 180451495200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 762869575929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 28.000 + 250.000 / 8 = 59.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2625^2) / (2 \times 2625/12 + 2512/59.25 + 2512/22) \\
&= 292761580816 \text{ mm}^4
\end{aligned}$$

- Section G2-16



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 28.0	75600	1314.00	99338400	130530657600	4939200
UPPER RIB	3 - 150.0 X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 32.0	86400	-1316.00	-113702400	149632358400	7372800
TOTAL		241200		-19509000	305373516000	35195812000

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 305373516000 + 35195812000 = 340569328000 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -19509000 / 241200 = -80.88 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 340569328000 - 241200 \times (-80.88)^2 = 338991379903 \text{ mm}^4$$

$$I_{22} = (b3^3 \times t_u / 12) + (b3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 28 / 12) + (2700^3 \times 32 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 196853995200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 28.000 / 2 + 32.000 / 2 = 2630.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2630^2) / (2 \times 2630/12 + 2512/28 + 2512/32) \\
&= 287836494039 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

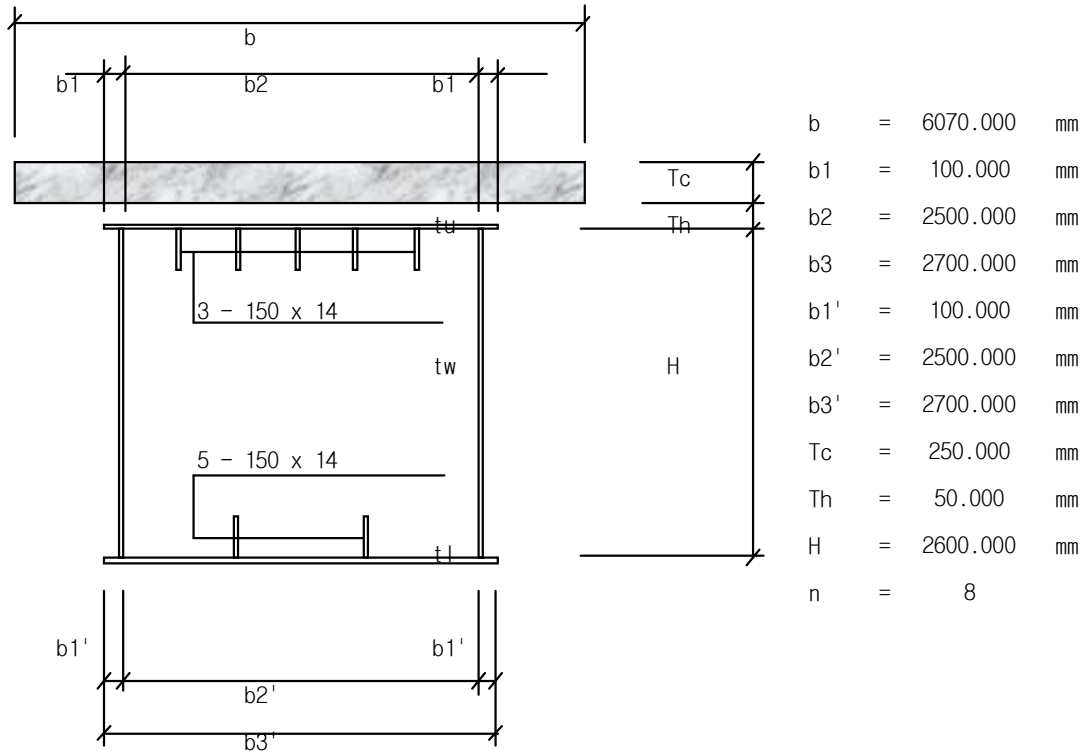
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 241200 + 1517500 / 8 = 430888 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - -80.883 + 50.000 + 250.000 / 2 = 1555.88 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1555.883 \times 241200 / 430888 = 870.94 \text{ mm} \\
dvs &= dv - dvc = 1555.883 - 870.944 = 684.94 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 338991379903 + 7903645833 / 8 + 241200 \times 684.939^2 \\
&\quad + 1517500 / 8 \times 870.944^2 = 597022488278 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 196853995200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 779272075929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 28.000 + 250.000 / 8 = 59.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2630^2) / (2 \times 2630/12 + 2512/59.25 + 2512/32) \\
&= 312190964911 \text{ mm}^4
\end{aligned}$$

- Section G2-17



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 28.0	75600	1314.00	99338400	130530657600	4939200
UPPER RIB	3 - 150.0 X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 28.0	75600	-1314.00	-99338400	130530657600	4939200
TOTAL		230400		-5145000	286271815200	35193378400

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 286271815200 + 35193378400 = 321465193600 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -5145000 / 230400 = -22.33 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 321465193600 - 230400 \times (-22.33)^2 = 321350301998 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 28 / 12) + (2700^3 \times 28 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 190292995200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 28.000 / 2 + 28.000 / 2 = 2628.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2628^2) / (2 \times 2628/12 + 2512/28 + 2512/28) \\
&= 282334051749 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

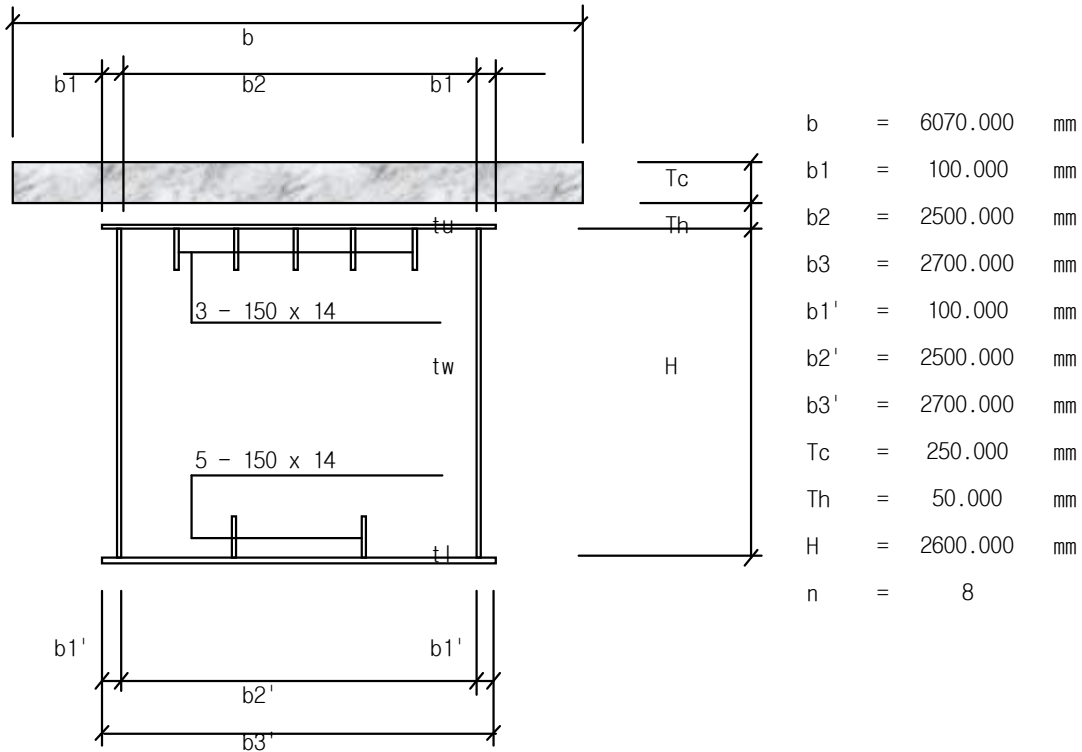
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 230400 + 1517500 / 8 = 420088 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 22.331 + 50.000 + 250.000 / 2 = 1497.33 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1497.331 \times 230400 / 420088 = 821.22 \text{ mm} \\
dvs &= dv - dvc = 1497.331 - 821.222 = 676.11 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 321350301998 + 7903645833 / 8 + 230400 \times 676.109^2 \\
&\quad + 1517500 / 8 \times 821.222^2 = 555585707256 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 190292995200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 772711075929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 28.000 + 250.000 / 8 = 59.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2628^2) / (2 \times 2628/12 + 2512/59.25 + 2512/28) \\
&= 305767013264 \text{ mm}^4
\end{aligned}$$

- Section G2-18



① 합성전 단면

구 분	규 격				As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	lo(mm ⁴)
UPPER FL.	1	-	2700.0	X 18.0	48600	1309.00	63617400	83275176600	1312200
UPPER RIB	3	-	150.0	X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2	-	2600.0	X 12.0	62400				35152000000
LOWER RIB	5	-	150.0	X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1	-	2700.0	X 28.0	75600	-1314.00	-99338400	130530657600	4939200
TOTAL					203400		-40866000	239016334200	35189751400

$$I_{s'} = \sum A s Y^2 + \sum I_0$$

$$= 239016334200 + 35189751400 = 274206085600 \text{ mm}^4$$

$$\delta s = \frac{\sum AsY}{\sum As} = \frac{-40866000}{203400} = -200.91 \text{ mm}$$

$$I_{33} = I_{s'} - \sum A_s \times \delta s^2$$

$$= 274206085600 - 203400 \times -200.914^2 = 265995515512 \text{ mm}^4$$

$$\begin{aligned}
 I_{22} &= (b3^3 \times t_u / 12) + (b3^{13} \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b2 / 2 + t_w / 2)^2)) \times 2 \\
 &= (2700^3 \times 18 / 12) + (2700^3 \times 28 / 12) + ((2600 \times 12^3 / 12) \\
 &\quad + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 173890495200 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2 = 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 18.000 / 2 + 28.000 / 2 = 2623.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2623^2) / (2 \times 2623/12 + 2512/18 + 2512/28) \\
&= 260577589682 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

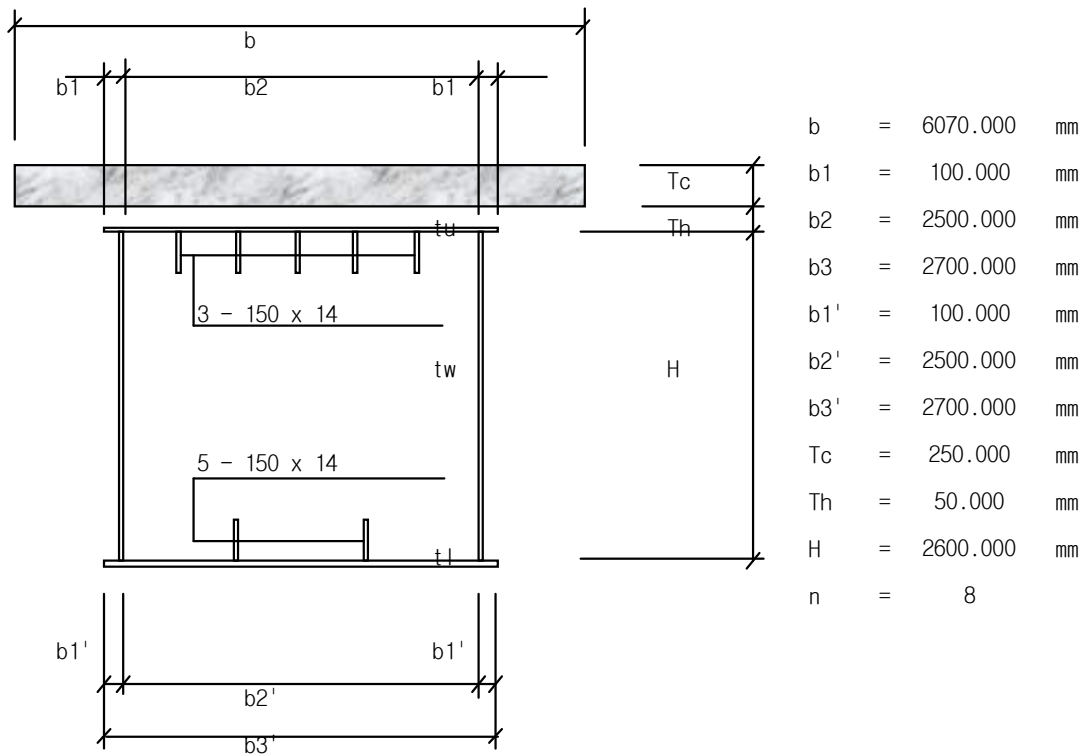
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 203400 + 1517500 / 8 = 393088 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - (-200.914) + 50.000 + 250.000 / 2 = 1675.91 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1675.914 \times 203400 / 393088 = 867.19 \text{ mm} \\
dvs &= dv - dvc = 1675.914 - 867.189 = 808.73 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 265995515512 + 7903645833 / 8 + 203400 \times 808.726^2 \\
&\quad + 1517500 / 8 \times 867.189^2 = 542662748134 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 173890495200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 756308575929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 18.000 + 250.000 / 8 = 49.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2623^2) / (2 \times 2623/12 + 2512/49.25 + 2512/28) \\
&= 300506346136 \text{ mm}^4
\end{aligned}$$

- Section G2-19



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 10.0	27000	1305.00	35235000	45981675000	225000
UPPER RIB	3 - 150.0 X 14.0	6300	1225.00	7717500	9453937500	11812500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1311.00	-77873400	102092027400	2395800
TOTAL		165600		-47783400	173284202400	35186120800

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 173284202400 + 35186120800 = 208470323200 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= -47783400 / 165600 = -288.55 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 208470323200 - 165600 \times (-288.547)^2 = 194682561633 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 10 / 12) + (2700^3 \times 22 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 150926995200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 10.000 / 2 + 22.000 / 2 = 2616.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2616^2) / (2 \times 2616/12 + 2512/10 + 2512/22) \\
&= 215543661400 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

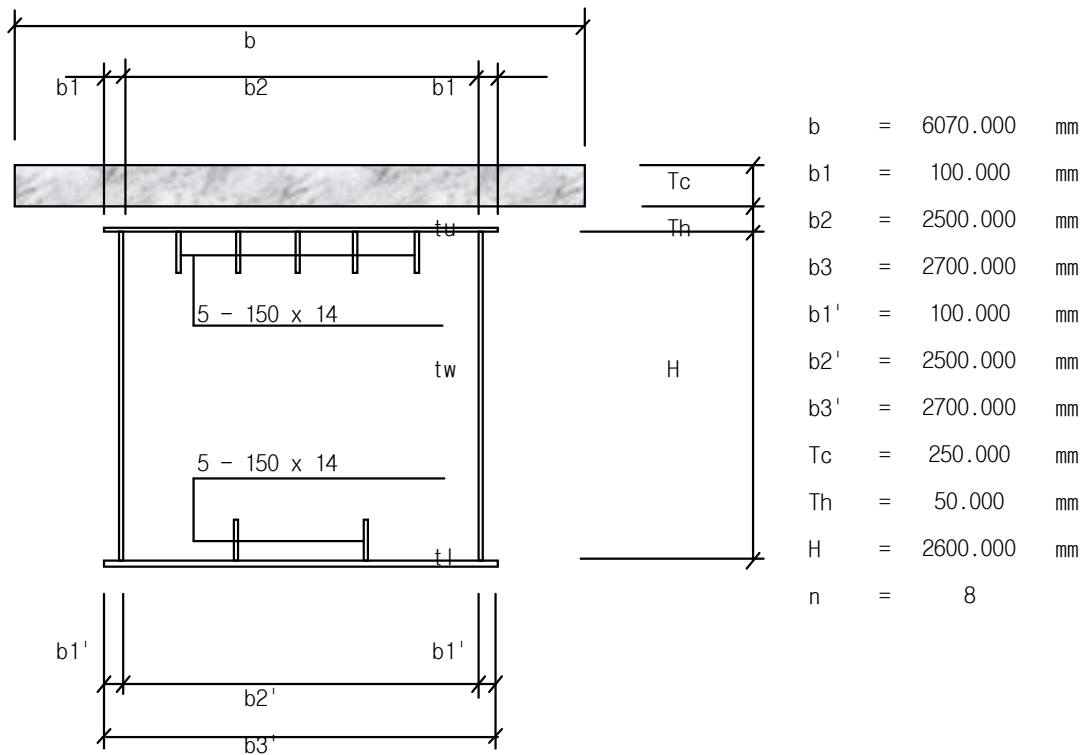
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 165600 + 1517500 / 8 = 355288 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - -288.547 + 50.000 + 250.000 / 2 = 1763.55 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1763.547 \times 165600 / 355288 = 821.99 \text{ mm} \\
dvs &= dv - dvc = 1763.547 - 821.992 = 941.56 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 194682561633 + 7903645833 / 8 + 165600 \times 941.555^2 \\
&\quad + 1517500 / 8 \times 821.992^2 = 470645538455 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 150926995200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 733345075929 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 250.000 / 8 = 41.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2616^2) / (2 \times 2616/12 + 2512/41.25 + 2512/22) \\
&= 282668576781 \text{ mm}^4
\end{aligned}$$

- Section G2-20



① 합성전 단면

구 분	구 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	1 - 2700.0 X 12.0	32400	1306.00	42314400	55262606400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1225.00	12862500	15756562500	19687500
W E B	2 - 2600.0 X 12.0	62400				35152000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1225.00	-12862500	15756562500	19687500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1306.00	-42314400	55262606400	388800
TOTAL		148200		0	142038337800	35192152600

$$I_s' = \sum AsY^2 + \sum I_o$$

$$= 142038337800 + 35192152600 = 177230490400 \text{ mm}^4$$

$$\delta s = \sum AsY / \sum As$$

$$= 0 / 148200 = 0.00 \text{ mm}$$

$$I_{33} = I_s' - \sum As \times \delta s^2$$

$$= 177230490400 - 148200 \times 0.00^2 = 177230490400 \text{ mm}^4$$

$$I_{22} = (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2$$

$$= (2700^3 \times 12 / 12) + (2700^3 \times 12 / 12) + ((2600 \times 12^3 / 12) + (2600 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 137804995200 \text{ mm}^4$$

- 비틀림 강성

$$b_k = b_2 + t_w / 2 \times 2$$

$$= 2500.000 + 12.000 / 2 \times 2 = 2512.00 \text{ mm}$$

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2600.000 + 12.000 / 2 + 12.000 / 2 = 2612.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2612^2) / (2 \times 2612/12 + 2512/12 + 2512/12) \\
&= 201645129210 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 250.000 = 1517500 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 148200 + 1517500 / 8 = 337888 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 250.000^3 / 12 = 7903645833 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2600.000 / 2 - 0.000 + 50.000 + 250.000 / 2 = 1475.00 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1475.000 \times 148200 / 337888 = 646.95 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1475.000 - 646.946 = 828.05 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 177230490400 + 7903645833 / 8 + 148200 \times 828.054^2 \\
&\quad + 1517500 / 8 \times 646.946^2 = 359226888635 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 137804995200 + 6070.000^3 \\
&\quad \times 250.000 / 12 / 8 = 720223075929 \text{ mm}^4
\end{aligned}$$

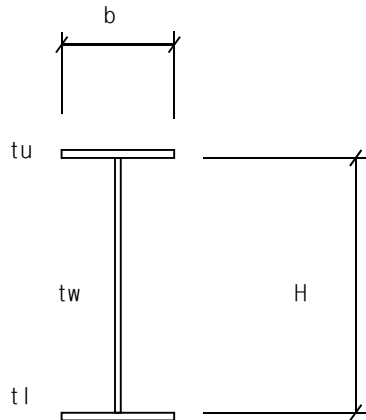
- 비틀림 강성

* 합성단면의 K값 산정시 CON'C SLAB의 두께를 강재로 환산하여 적용한다.

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 250.000 / 8 = 43.25 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2612^2) / (2 \times 2612/12 + 2512/43.25 + 2512/12) \\
&= 245045223097 \text{ mm}^4
\end{aligned}$$

2-2. 가로보 및 세로보 단면상수 산정

- 가로보 Section 1 : 교대 및 교각



$$b_u = 300.00 \text{ mm}$$

$$b_l = 300.00 \text{ mm}$$

$$H = 2000.00 \text{ mm}$$

$$t_u = 12.00 \text{ mm}$$

$$t_w = 12.00 \text{ mm}$$

$$t_l = 12.00 \text{ mm}$$

구 분	규	격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	300.00	X 12.00	3600.0	1006.00	3621600	3643329600	43200
W E B	2000.00	X 12.00	24000.0				80000000000
LOWER FL.	300.00	X 12.00	3600.0	-1006.00	-3621600	3643329600	43200
TOTAL			31200.0		0	7286659200	8000086400

$$I_{33} = \sum AsY^2 + \sum I_o$$

$$= 7286659200 + 8000086400 = 15286745600 \text{ mm}^4$$

$$I_{22} = (b_u^3 \times t_u / 12) + (b_l^3 \times t_l / 12) + (H \times t_w^3 / 12)$$

$$= (300^3 \times 12 / 12) + (300^3 \times 12 / 12) + (2000 \times 12^3 / 12)$$

$$= 54288000 \text{ mm}^4$$

모델링시의 가로보 강성보정은 $I' = I \times (L' / L)^3$ 에 의한다.

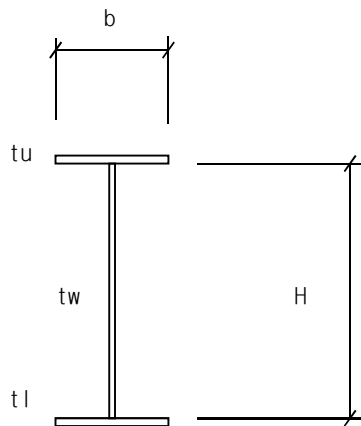
여기서, L, I : 실제 가로보의 길이 및 강성 L', I' : 모델링시 가로보의 길이 및 보정강성

- 비틀림 강성

$$K = \sum (b \times t^3) / 3$$

$$= (300 \times 12^3 + 300 \times 12^3 + 2000 \times 12^3) / 3 = 1497600 \text{ mm}^4$$

- 가로보 Section 2 : 일반부



bu

=

300.00

mm

bl

=

300.00

mm

H

=

1500.00

mm

tu

=

10.00

mm

tw

=

10.00

mm

tl

=

10.00

mm

구 분	규격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	lo(mm ⁴)
UPPER FL.	300.00 X 10.00	3000.0	755.00	2265000	1710075000	25000
W E B	1500.00 X 10.00	15000.0				2812500000
LOWER FL.	300.00 X 10.00	3000.0	-755.00	-2265000	1710075000	25000
TOTAL		21000.0		0	3420150000	2812550000

I33

=

$\sum AsY^2 + \sum lo$

=

3420150000

+

2812550000

=

6232700000

mm⁴

I22

=

$(bu^3 \times tu / 12) + (bl^3 \times tl / 12) + (H \times tw^3 / 12)$

=

$(300^3 \times 10 / 12) + (300^3 \times 10 / 12) + (1500 \times 10^3 / 12)$

=

45125000

mm⁴

모델링시의 가로보 강성보정은 $I'=I \times (L'/L)^3$ 에 의한다.

여기서, L,l : 실제 가로보의 길이 및 강성 L', l' : 모델링시 가로보의 길이 및 보정강성

- 비틀림 강성

K

=

$\sum (b \times t^3) / 3$

=

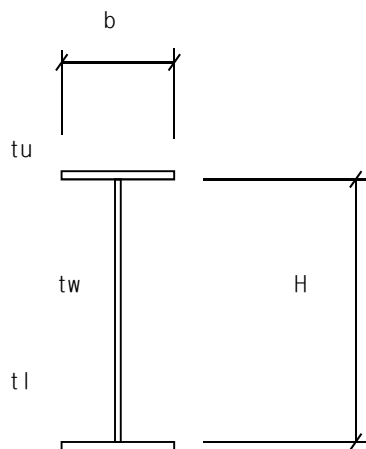
$(300 \times 10^3 + 300 \times 10^3 + 1500 \times 10^3) / 3$

=

700000

mm⁴

- 세로보 Section 1



$$\begin{aligned} b_u &= 250.00 \text{ mm} \\ b_l &= 250.00 \text{ mm} \\ H &= 800.00 \text{ mm} \\ t_u &= 10.00 \text{ mm} \\ t_w &= 10.00 \text{ mm} \\ t_l &= 10.00 \text{ mm} \end{aligned}$$

구 분	규 격	As(mm ²)	Y(mm)	AsY(mm ³)	AsY ² (mm ⁴)	Io(mm ⁴)
UPPER FL.	250.00 X 10.00	2500.0	405.00	1012500	410062500	20833
W E B	800.00 X 10.00	8000.0				426666667
LOWER FL.	250.00 X 10.00	2500.0	-405.00	-1012500	410062500	20833
TOTAL		13000.0		0	820125000	426708333

$$\begin{aligned} I_{33} &= \sum AsY^2 + \sum I_o \\ &= 820125000 + 426708333 = 1246833333 \text{ mm}^4 \\ I_{22} &= (b_u^3 \times t_u / 12) + (b_l^3 \times t_l / 12) + (H \times t_w^3 / 12) \\ &= (250^3 \times 10 / 12) + (250^3 \times 10 / 12) + (800 \times 10^3 / 12) \\ &= 26108333 \text{ mm}^4 \end{aligned}$$

모델링시의 가로보 강성보정은 $I' = I \times (L' / L)^3$ 에 의한다.

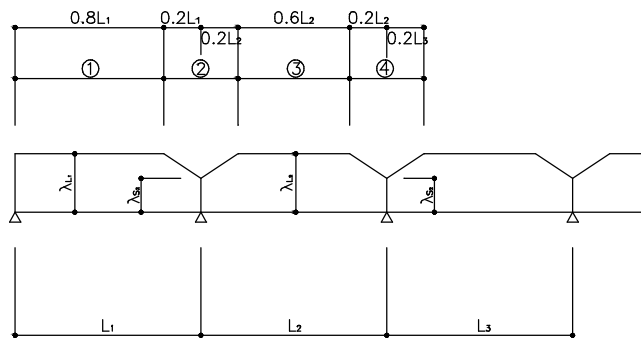
여기서, L, I : 실제 가로보의 길이 및 강성 L', I' : 모델링시 가로보의 길이 및 보정강성

- 비틀림 강성

$$\begin{aligned} K &= \sum (b \times t^3) / 3 \\ &= (250 \times 10^3 + 250 \times 10^3 + 800 \times 10^3) / 3 = 433333 \text{ mm}^4 \end{aligned}$$

3. 플랜지 및 슬래브 유효폭

3-1. 플랜지 유효폭 (도.설 3.8.3.4)



상부 : 복부간격 $2b = 2.500$ m, 플랜지돌출폭 $b_e = 0.100$ m

하부 : 복부간격 $2b = 2.500$ m, 플랜지돌출폭 $b_e = 0.100$ m

$L_1 = 55.000$ m

$L_2 = 55.000$ m

$L_3 = 55.000$ m

1. 제 1, 3 구간 정모멘트부

$$l = 0.8 \times L_1 = 0.8 \times 55 = 44.000 \text{ m}$$

· 상 부

$$b/l = 1.25 / 44 = 0.028$$

여기서, $b/l \leq 0.05$ 이므로

$$\lambda L_1 = b = 1.25 \text{ m}$$

$$\therefore \text{플랜지 유효폭 } B = 2 \times (\lambda L_1 + b_e) = 2.700 \text{ m}$$

· 하 부

$$b/l = 1.25 / 44 = 0.028$$

여기서, $b/l \leq 0.05$ 이므로

$$\lambda L_1 = b = 1.25 \text{ m}$$

$$\therefore \text{플랜지 유효폭 } B = 2 \times (\lambda L_1 + b_e) = 2.700 \text{ m}$$

2. 제 1, 2 구간 부모멘트부

$$l = 0.2 \times (L_1 + L_2) = 0.2 \times (55 + 55) = 22.000 \text{ m}$$

· 상 부

$$b/l = 1.25 / 22 = 0.057$$

여기서, $0.02 < b/l < 0.30$ 이므로

$$\lambda S_1 = \{1.06 - 3.2(b/l) + 4.5(b/l)^2\} \cdot b = 1.116 \text{ m}$$

$$\therefore \text{플랜지 유효폭 } B = 2 \times (\lambda S_1 + b_e) = 2.432 \text{ m}$$

· 하 부

$$b/l = 1.25 / 22 = 0.057$$

여기서, $0.02 < b/l < 0.30$ 이므로

$$\lambda S1 = \{1.06 - 3.2(b/l) + 4.5(b/l)^2\} \cdot b = 1.116 \text{ m}$$

$$\therefore \text{플랜지 유효폭 } B = 2 \times (\lambda S1 + b_e) = 2.432 \text{ m}$$

3. 제 2 경간 정모멘트부

$$l = 0.6 \times L2 = 0.6 \times 55 = 33.000 \text{ m}$$

· 상 부

$$b/l = 1.25 / 33 = 0.038$$

여기서, $b/l \leq 0.05$ 이므로

$$\lambda L2 = b = 1.25 \text{ m}$$

$$\therefore \text{플랜지 유효폭 } B = 2 \times (\lambda L2 + b_e) = 2.700 \text{ m}$$

· 하 부

$$b/l = 1.25 / 33 = 0.038$$

여기서, $b/l \leq 0.05$ 이므로

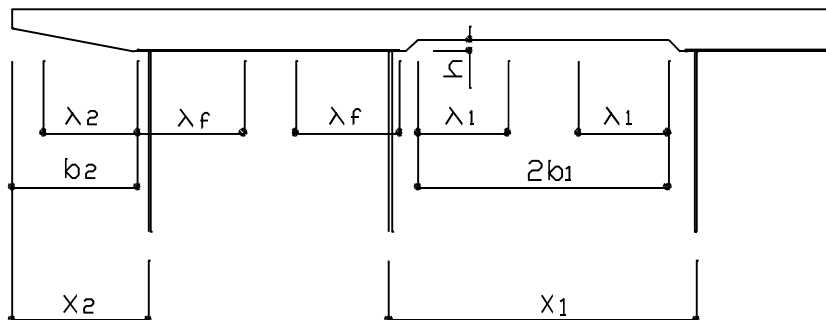
$$\lambda L2 = b = 1.25 \text{ m}$$

$$\therefore \text{플랜지 유효폭 } B = 2 \times (\lambda L2 + b_e) = 2.700 \text{ m}$$

3-2. 슬래브 유효폭 (도.설 3.8.3.4)

플랜지 상단 부분에서의 바닥판에 대한 전단 지연도 상판내의 전단지연과 같은 정도가 되는 것으로 간주 한다

1) GIRDER - 1



$X1 = 5.300$: 인접한 GIRDER의 복부사이의 간격

$X2 = 0.930$: 외측 GIRDER 복부에서 캔틸레버 끝단까지의 거리

$h = 0.050$: 현치 높이

$b_e = 0.100$: 플랜지의 돌출폭

$$2b_1 = X1 - 2(b_e + h) = 5.3 - 2 \times (0.1 + 0.05) = 5.000 \text{ m}$$

$$b_2 = X2 - b_e = 0.93 - 0.1 = 0.830 \text{ m}$$

1. 제 1,3 경간 정모멘트부

$$l = 0.8 \times L1 = 0.8 \times 55 = 44.000 \text{ m}$$

$$b1 / l = 2.5 / 44 = 0.057$$

여기서, $0.05 < b/l < 0.30$ 이므로

$$\lambda 1 = \{1.1 - 2(b/l)\} \cdot b = 2.466 \text{ m}$$

$$b2 / l = 0.83 / 44 = 0.019$$

여기서, $b/l \leq 0.05$ 이므로

$$\lambda 2 = b = 0.83 \text{ m}$$

슬래브 유효폭

$$B = \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 6.046 \text{ m}$$

2. 제 1, 2 경간 부모멘트부

$$l = 0.2 \times (L1 + L2) = 0.2 \times (55 + 55) = 22.000 \text{ m}$$

$$b1 / l = 2.5 / 22 = 0.114$$

여기서, $0.02 < b/l < 0.30$ 이므로

$$\lambda 1 = \{1.06 - 3.2(b/l) + 4.5(b/l)^2\} \cdot b = 1.886 \text{ m}$$

$$b2 / l = 0.83 / 22 = 0.038$$

여기서, $0.02 < b/l < 0.30$ 이므로

$$\lambda 2 = \{1.06 - 3.2(b/l) + 4.5(b/l)^2\} \cdot b = 0.785 \text{ m}$$

슬래브 유효폭

$$B = \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 5.153 \text{ m}$$

3. 제 2 경간 정모멘트부

$$l = 0.6 \times L2 = 0.6 \times 55 = 33.000 \text{ m}$$

$$b1 / l = 2.5 / 33 = 0.076$$

여기서, $0.05 < b/l < 0.30$ 이므로

$$\lambda 1 = \{1.1 - 2(b/l)\} \cdot b = 2.371 \text{ m}$$

$$b2 / l = 0.83 / 33 = 0.025$$

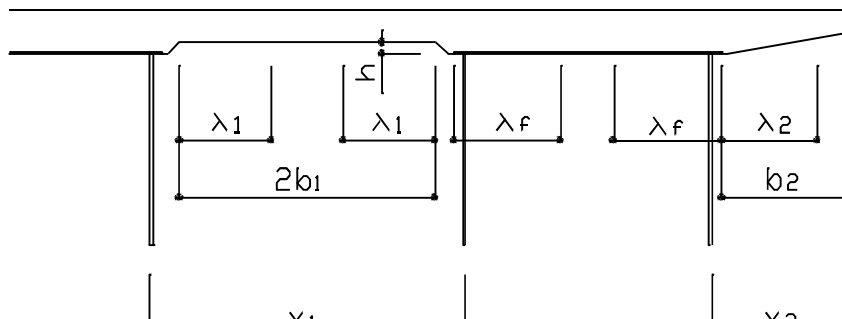
여기서, $b/l \leq 0.05$ 이므로

$$\lambda 2 = b = 0.83 \text{ m}$$

슬래브 유효폭

$$B = \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 5.951 \text{ m}$$

2) GIRDER - 2



$$\begin{aligned}
X1 &= 5.300 && \text{: 인접한 GIRDER의 복부사이의 간격} \\
X2 &= 0.920 && \text{: 외측 GIRDER 복부에서 캔틸레버 끝단까지의 거리} \\
h &= 0.050 && \text{: 현치 높이} \\
be &= 0.100 && \text{: 플랜지의 돌출폭} \\
2b1 &= X1 - 2(be + h) = 5.3 - 2 \times (0.1 + 0.05) &= & 5.000 \quad \text{m} \\
b2 &= X2 - be = 0.92 - 0.1 &= & 0.820 \quad \text{m}
\end{aligned}$$

1. 제 1,3 경간 정모멘트부

$$\begin{aligned}
l &= 0.8 \times L1 = 0.8 \times 55 = 44.000 \quad \text{m} \\
b1 / l &= 2.5 / 44 = 0.057 \\
\text{여기서, } 0.05 &< b/l < 0.30 \text{ 이므로} \\
\lambda 1 &= \{1.1 - 2(b/l)\} \cdot b = 2.466 \quad \text{m} \\
b2 / l &= 0.82 / 44 = 0.019 \\
\text{여기서, } b/l &\leq 0.05 \text{ 이므로} \\
\lambda 2 &= b = 0.82 \quad \text{m} \\
\text{슬래브 유효폭} \\
B &= \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 6.036 \quad \text{m}
\end{aligned}$$

2. 제 1, 2 경간 부모멘트부

$$\begin{aligned}
l &= 0.2 \times (L1 + L2) = 0.2 \times (55 + 55) = 22.000 \quad \text{m} \\
b1 / l &= 2.5 / 22 = 0.114 \\
\text{여기서, } 0.02 &< b/l < 0.30 \text{ 이므로} \\
\lambda 1 &= \{1.06 - 3.2(b/l) + 4.5(b/l)^2\} \cdot b = 1.886 \quad \text{m} \\
b2 / l &= 0.82 / 22 = 0.037 \\
\text{여기서, } 0.02 &< b/l < 0.30 \text{ 이므로} \\
\lambda 2 &= \{1.06 - 3.2(b/l) + 4.5(b/l)^2\} \cdot b = 0.777 \quad \text{m} \\
\text{슬래브 유효폭} \\
B &= \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 5.145 \quad \text{m}
\end{aligned}$$

3. 제 2 경간 정모멘트부

$$\begin{aligned}
l &= 0.6 \times L2 = 0.6 \times 55 = 33.000 \quad \text{m} \\
b1 / l &= 2.5 / 33 = 0.076 \\
\text{여기서, } 0.05 &< b/l < 0.30 \text{ 이므로} \\
\lambda 1 &= \{1.1 - 2(b/l)\} \cdot b = 2.371 \quad \text{m} \\
b2 / l &= 0.82 / 33 = 0.025 \\
\text{여기서, } b/l &\leq 0.05 \text{ 이므로} \\
\lambda 2 &= b = 0.82 \quad \text{m} \\
\text{슬래브 유효폭} \\
B &= \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 5.941 \quad \text{m}
\end{aligned}$$

4. 부재력 요약

[1경간 정모멘트부]

[BENDING MOMENT]					
거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	13,385.002	3,311.147	7,312.892	522.388	0.557
G2	13,375.338	3,533.503	8,098.785	522.185	0.557

[SHEAR FORCE]					
거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	79.427	18.002	324.313	20.937	
G2	79.338	20.904	327.971	20.929	

[TORSION MOMENT]					
거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	0.649	5.226	555.630	0.006	
G2	6.717	5.276	344.019	0.005	

[2경간 정모멘트부]

[BENDING MOMENT]					
거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	3,219.428	830.715	5,234.670	319.300	-0.197
G2	3,215.131	983.542	5,793.170	319.182	-0.197

[SHEAR FORCE]					
거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	134.345	34.175	363.280	41.537	
G2	134.175	40.113	358.687	41.520	

[TORSION MOMENT]					
거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	0.000	0.000	532.990	0.027	
G2	0.000	0.000	302.226	0.026	

[3경간 정모멘트부]

[BENDING MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	13,385.002	3,311.147	7,312.891	522.388	0.557
G2	13,375.338	3,533.503	8,098.785	522.185	0.557

[SHEAR FORCE]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	192.904	47.272	342.131	20.937	
G2	192.668	55.711	352.919	20.929	

[TORSION MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	0.000	0.000	548.699	0.006	
G2	0.000	0.000	313.926	0.005	

[1경간 부모멘트부]

[BENDING MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-18,069.466	-4,431.802	-7,401.577	-1,142.815	-0.197
G2	-18,051.719	-4,970.766	-9,149.959	-1,142.364	-0.197

[SHEAR FORCE]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-1,919.624	-459.913	-862.520	-41.553	
G2	-1,917.673	-521.651	-1,025.813	-41.536	

[TORSION MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-0.023	-27.108	-935.481	-0.081	
G2	-0.176	-28.926	-795.502	-0.083	

[2경간 부모멘트부]

[BENDING MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-18,069.466	-4,431.802	-7,401.577	-1,142.815	-0.197
G2	-18,051.719	-4,970.766	-9,149.959	-1,142.364	-0.197

[SHEAR FORCE]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-1,583.022	-376.911	-818.416	-41.553	
G2	-1,581.203	-438.662	-975.317	-41.536	

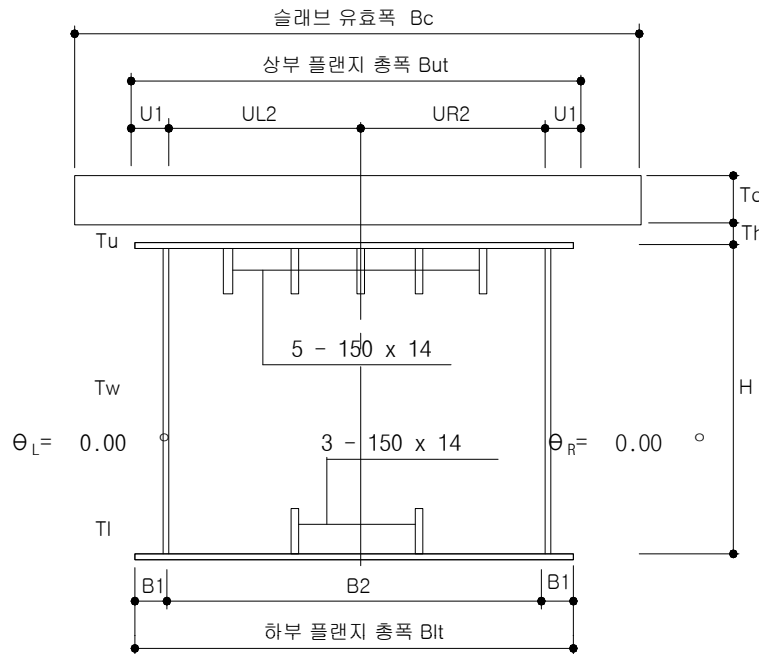
[TORSION MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-0.652	-6.040	-891.096	-0.081	
G2	-0.357	-7.822	-753.157	-0.083	

5. 단면검토

5-1. 1경간 최대 정모멘트 단면검토(G1)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.600 m

Bc = 6.036 m

UL2= 1.250 , UR2= 1.250 m

B2 = 2.500 m

But= 2.700 , Blt= 2.700 m

상하 플랜지 유효폭

Bue= 2.700 , Ble= 2.700 m

Tc = 0.250 m

Th = 0.050 m

Tu = 0.016 m

TI = 0.022 m

Tw = 0.012 m

U1 = 0.100 m

B1 = 0.100 m

RIB 150 x 14 mm , 150 x 14 mm

구 분	단 위	입력 DATA
Es : 강의 탄성계수	MPa	210000
Ec : 콘크리트의 탄성계수	MPa	26702
ϵ_s : 바닥판 콘크리트의 건조수축에 의한 최종수축율		0.00018
α : 강재 및 콘크리트의 선팅창계수		0.000012
ϕ_2 : 건조수축에 의한 크리이프계수		4
n : 강과 콘크리트의 탄성계수비		8
t : 강과 콘크리트의 온도차	℃	10
Ms : 합성전 고정하중에 의한 모멘트	kN · m	13375.338
Msc : 합성후 고정하중에 의한 모멘트	kN · m	3533.503
Mv : 활하중+지점침하에 의한 모멘트	kN · m	8620.970
Ss : 합성전 고정하중에 의한 전단력	kN	79.338
Ssc : 합성후 고정하중에 의한 전단력	kN	20.904
Sv : 활하중+지점침하에 의한 전단력	kN	348.900
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	6.717
Msct : 합성후 고정하중에 의한 비틀림모멘트	kN · m	5.276
Mvt : 활하중+지점침하에 의한 비틀림모멘트	kN · m	344.024

< 참고 > 합성전 고정하중 : 강재자중 + 바닥판콘크리트자중

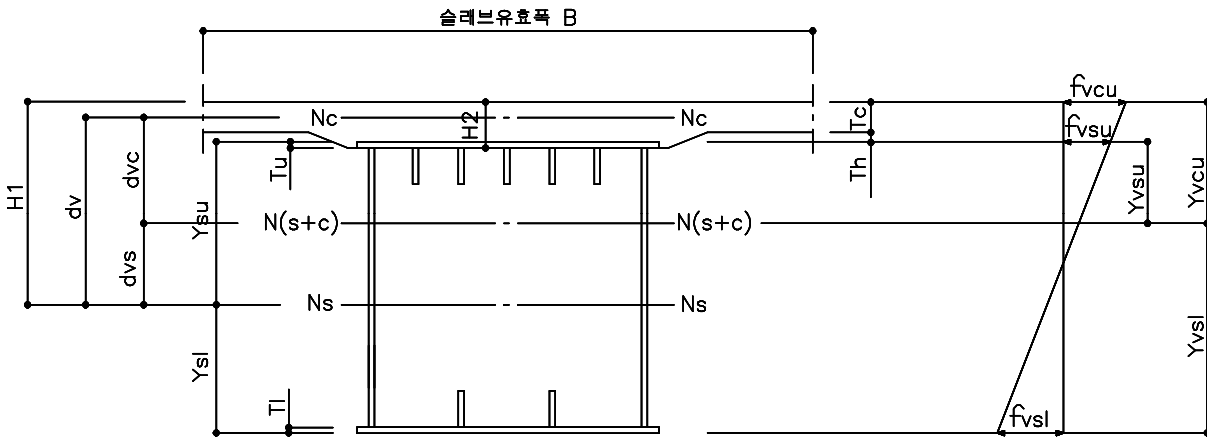
합성후 고정하중 : 방호벽 + PAVEMENT자중

단 면 제 원

단 면	B(mm)	H(mm)	A(mm ²)	Y(mm)	A*Y(mm ³)	A*Y2(mm ⁴)	Ix(mm ⁴)
1 - UPPER FLANGE	2700.0	16.0	43200	1308.0	56505600	73909324800	921600
5 - UPPER RIB	14.0	150.0	10500	1225.0	12862500	15756562500	19687500
1 - L_WEB	12.0	2600.0	31200	0.0	0	0	17576000000
1 - R_WEB	12.0	2600.0	31200	0.0	0	0	17576000000
3 - LOWER RIB	14.0	150.0	6300	-1225.0	-7717500	9453937500	11812500
1 - LOWER FLANGE	2700.0	22.0	59400	-1311.0	-77873400	1.02092E+11	2395800
강단면 합계			181800		-16222800	2.01212E+11	35186817400
1 - RC SLAB	6036.0	250.0	1509000	1475.0	2225775000	3283018125000	7859375000

$$* A_s = 181800 \text{ mm}^2, A_c = 1509000 \text{ mm}^2$$

2) 응력 검토



(1) 합성 전

$$I_s' = A_s \cdot Y_2 + \sum I_s = \text{#####} + 35186817400.0 = 236398669600 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = \frac{-16222800}{181800} = -89.234 \text{ mm}$$

$$I_s = I_{s'} - A_s \cdot \delta s^2 = \text{#####} - 181800 \times -89.234^2 = 234951039018 \text{ nm}^4$$

$$Y_{su} = H/2 + T_u - \delta_s = 2600.0 / 2 + 16.0 - -89.234 = 1405.234 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1405.234 - 2638.000 = -1232.766 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6578928.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 79.997 \text{ MPa}$$

$$f_{sI} = M_s \cdot Y_{sI} / I_s = -70.179 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot T_w) = 1.314 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 370425.0 \text{ mm}^2$$

$$I_{c/n} = 982421875 \text{ nm}^4$$

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$$\begin{aligned}
dvs &= dv - dvc = 796.5 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 892.7 \text{ mm} \\
Yvcl &= Yvcu - Tc = 642.7 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 608.7 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2029.3 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 462448199036 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6618178.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.853 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.614 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 4.651 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -15.506 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.368 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 2.080 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.498 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 11.348 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -37.830 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 7.757 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 276112.5 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1029.9 \text{ mm} & K = 0.557 \\
ds1 &= dv - dc1 = 534.3 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1154.9 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 904.9 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 870.9 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1767.1 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 387385247604 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 1106463 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 1106463 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 1139584798 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.853 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.614 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.484 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.271 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 5.434 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = 4.440 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 244675.000 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1162.3 \text{ mm}$$

$$ds2 = dv - dc2 = 402.0 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1287.3 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1037.3 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 1003.3 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1634.7 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 349588954550.6 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 2376675 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2762332105 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon_s = -0.934 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon_s = -0.980 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 14.129 \text{ MPa}$$

$$fvsl2 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 2.519 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 4753350 \text{ N}$$

$$Mvt = P1 \cdot dvc = 3649179228 \text{ N} \cdot \text{mm}$$

$$fcut1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon_t = -1.110 \text{ MPa}$$

$$fclt1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon_t = -1.247 \text{ MPa}$$

$$fsut1 = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 15.508 \text{ MPa}$$

$$fslt1 = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 3.913 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 9.439 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(8) 조합응력의 검토 (도.설 3.4.2.1)

$$i = 0.65(\phi/n)^2 + 0.13(\phi/n) + 1.0$$

$$= 0.650 \times (0.0 / 6)^2 + 0.130 \times (0.0 / 6) + 1.0 = 1.000$$

$$\therefore \phi = (f_1 - f_2)/f_1 \approx 0$$

여기서, n : 종리브에 의해서 구분되는 Pannel의 수

i : 응력구배계수 ϕ : 응력구배

f_1, f_2 : 보강된 판의 양면의 응력

(단, $f_1 \geq f_2$ 이며 압축응력을 정(+)으로 한다.)

* 인장 (하부)플랜지의 허용응력 (SM490 사용)

$$f_{ta} = 190.0 \text{ MPa}$$

* 압축 (상부)플랜지의 허용응력 (SM490 사용)

$$t_u \geq \frac{b}{24 \cdot i \cdot n} = \frac{2500}{24 \times 1.000 \times 6} = 17.4 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190.0 \text{ MPa}$$

$$\frac{b}{24 \cdot i \cdot n} > t_u \geq \frac{b}{49 \cdot i \cdot n} = \frac{2500}{49 \times 1.000 \times 6} = 8.5 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190 - 3.9 \left(\frac{b}{(t_u \cdot i \cdot n) - 24} \right) = 182.0$$

$$\frac{b}{49 \cdot i \cdot n} > t_u \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.2 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 220000 \times \left\{ (t_u \cdot i \cdot n) / b \right\} = 324.403 \text{ MPa}$$

$$\text{사용 } t_u = 16.0 \text{ mm}$$

$$\text{따라서, } f_{ca} = 182.038 \text{ MPa}$$

* 철근콘크리트의 허용응력 (도.설 3.9.3)

$$f_{ca} = 0.4 \quad f_{ck} = 10.800 \text{ MPa}$$

$$(f_{ck} = 27 \text{ MPa 사용})$$

$$f_{ta} = 0.07 \quad f_{ck} = 1.890 \text{ MPa}$$

하중조합	CONCRETE				STEEL			
	작용응력(MPa)		허용응력(MPa)		작용응력(MPa)		허용응력(MPa)	
	상 연	하 연	상 연	하 연	상 연	하 연	상 연	하 연
1			10.800	10.800	79.997	-70.179	182.038	190.000
1+2+3	2.933	2.112	10.800	10.800	95.996	-123.515	182.038	190.000
1+2+3+4	2.449	1.841	10.800	10.800	101.430	-122.403	209.344	190.000
1+2+3+4+5	1.515	0.861	10.800	10.800	115.560	-119.884	209.344	190.000
1+2+3+4+5+6	0.405	-0.386	12.420	2.174	131.067	-115.971	236.649	218.500
1+2+3+4+5-6	2.624	2.108	12.420	12.420	100.052	-123.797	236.649	218.500

주) 압축응력을 정(+), 인장응력을 부(-)로 하였음.

허용응력의 활증 (도.설 3.9.3.1 참조)

(9) 합성응력의 검토 (도.설 3.8.2.4)

(상 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{131.067}{236.649} \right)^2 + \left(\frac{9.439}{110.000} \right)^2$$

$$= 0.307 + 0.007 = 0.314 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-123.515}{190.000} \right)^2 + \left(\frac{9.439}{110.000} \right)^2$$

$$= 0.420 + 0.007 = 0.427 < 1.2 \quad \mathbf{O.K.}$$

(10) 판의 최소두께 검토

압축(상부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = 10 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K. (합성형 스퍼드 설치)}$$

인장(하부)플랜지 (☞ 도.설.기 3.8.3.1 및 3.8.3.2)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 22 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 22 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 9.9 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/79.997)} = 1.541 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 4.6 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/131.067)} = 1.204 > 1.2 \Rightarrow 1.200$$

(11) 항복에 대한 안전도 검사 (☞ 도.설.해(2003) 3.9.3.2)

$\Sigma f = 1.3 \times (\text{합성전 사하중 응력} + \text{합성후 사하중}) + 2.15 \times \text{활하중에 의한 응력(충격포함)}$
 $+ (\text{크리프응력 변화량}) + (\text{건조수축응력변화량}) + (\text{온도차응력변화량})$ 의 조합 중에서
 가장 불리한 하중 조합에 대하여 검토

① 바닥판 콘크리트

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.853 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 2.933 - 0.853 = 2.080 \text{ MPa}$$

$$\Sigma f = 1.3 \times 0.853 + 2.15 \times 2.08 + (-0.484) + (-0.934) + (1.11) = 5.273 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times 0.853 + 2.15 \times 2.08 + (1.11) = 6.691 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 79.997 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 4.651 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 95.996 - 79.997 - 4.651 = 11.348 \text{ MPa}$$

$$\Sigma f = 1.3 \times (79.997 + 4.651) + 2.15 \times 11.348 + (5.434) + (14.129) + (15.508) = 169.512 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (79.997 + 4.651) + 2.15 \times 11.348 + (15.508) = 149.948 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -70.179 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -15.506 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -123.515 - -70.179 - -15.506 = -37.830 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-70.179 + -15.506) + 2.15 \times -37.83 + (1.112) + (2.519) + (-3.913) = -193.007 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (-70.179 + -15.506) + 2.15 \times -37.83 + (-3.913) = -196.638 \text{ MPa} < f_y = 315.0 \text{ MPa}$$

- 항복에 대한 안전도 검사 결과 집계

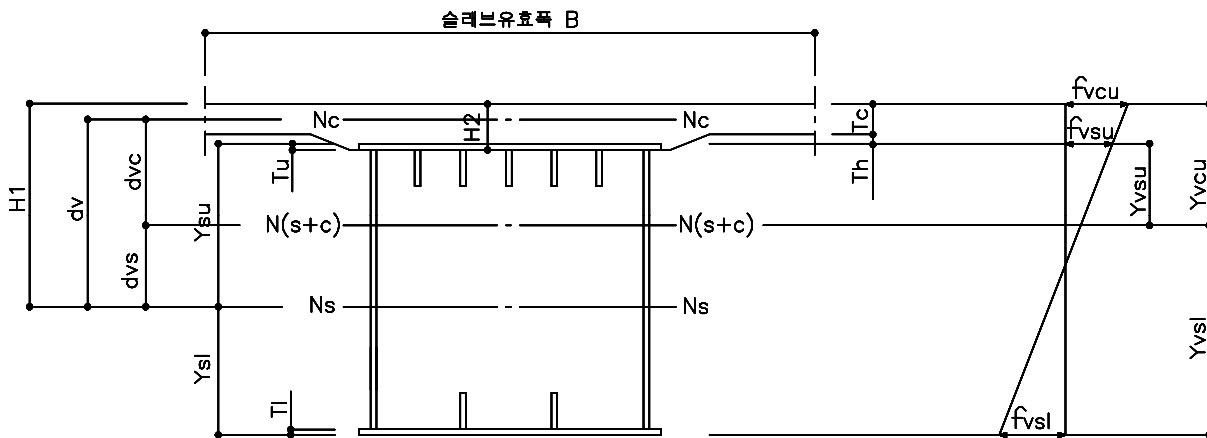
구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	5.273	16.200	0.K!!!	3.07
	크리프, 건조수축제외시	6.691	16.200	0.K!!!	2.42
상부플랜지	크리프, 건조수축 포함시	169.512	315.000	0.K!!!	1.85
	크리프, 건조수축제외시	149.948	315.000	0.K!!!	2.10
하부플랜지	크리프, 건조수축 포함시	-193.007	315.000	0.K!!!	1.63
	크리프, 건조수축제외시	-196.638	315.000	0.K!!!	1.60

단 면 제 원

단 면	B(mm)	H(mm)	A(mm ²)	Y(mm)	A*Y(mm ³)	A*Y ² (mm ⁴)	I _x (mm ⁴)
1 - UPPER FLANGE	2700.0	12.0	32400	1306.0	42314400	55262606400	388800
5 - UPPER RIB	14.0	150.0	10500	1225.0	12862500	15756562500	19687500
1 - L_WEB	10.0	2600.0	26000	0.0	0	0	14646666667
1 - R_WEB	10.0	2600.0	26000	0.0	0	0	14646666667
3 - LOWER RIB	14.0	150.0	6300	-1225.0	-7717500	9453937500	11812500
1 - LOWER FLANGE	2700.0	14.0	37800	-1307.0	-49404600	64571812200	617400
강단면 합계			139000		-1945200	1.45045E+11	29325839533
1 - RC SLAB	5941.0	250.0	1485250	1475.0	2190743750	3231347031250	7735677083

* As = 139000 mm² , Ac = 1485250 mm²

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = \text{#####} + 29325839533.3 = 174370758133 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -1945200 / 139000 = -13.994 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = \text{#####} - 139000 \times -13.994^2 = 174343536529 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2600.0 / 2 + 12.0 - -13.994 = 1325.994 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1325.994 - 2626.000 = -1300.006 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6558630.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 24.453 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = -23.974 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 2.580 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 324656.3 \text{ mm}^2$$

$$I_c/n = 966959635 \text{ mm}^4$$

$$I_{cs} = I_c/n + A_v \cdot Y_{cs}^2 = 1432000000 \text{ mm}^4$$

$$637.5$$

$$\begin{aligned}
dvs &= dv - dvc = 851.5 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 762.5 \text{ mm} \\
Yvcl &= Yvcu - Tc = 512.5 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 474.5 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2151.5 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 351543256860 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6597848.8 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.267 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.179 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 1.328 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -6.019 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.771 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 1.657 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.114 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 8.250 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -37.408 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 9.987 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 231828.1 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 892.8 \text{ mm} & K = -0.197 \\
ds1 &= dv - dc1 = 596.2 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1017.8 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 767.8 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 729.8 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1896.2 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 298226770398 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 331137 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 331137 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 295630651 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.267 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.179 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.190 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.099 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 1.286 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = -4.700 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 200885.417 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1030.3 \text{ mm}$$

$$ds2 = dv - dc2 = 458.7 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1155.3 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 905.3 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 867.3 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1758.7 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 269604002679.8 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 2339269 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2410124782 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon_s = -1.175 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon_s = -1.156 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 10.117 \text{ MPa}$$

$$fvs12 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 14.742 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 4678538 \text{ N}$$

$$Mvt = P1 \cdot dvc = 2982594181 \text{ N} \cdot \text{mm}$$

$$fcut1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon_t = -1.562 \text{ MPa}$$

$$fclt1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon_t = -1.510 \text{ MPa}$$

$$fsut1 = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 13.618 \text{ MPa}$$

$$fslt1 = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 18.007 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 13.339 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(8) 조합응력의 검토 (도.설 3.4.2.1)

$$i = 0.65(\phi/n)^2 + 0.13(\phi/n) + 1.0$$

$$= 0.650 \times (0.0 / 6)^2 + 0.130 \times (0.0 / 6) + 1.0 = 1.000$$

$$\therefore \phi = (f_1 - f_2)/f_1 \approx 0$$

여기서, n : 종리브에 의해서 구분되는 Pannel의 수

i : 응력구배계수 ϕ : 응력구배

f_1, f_2 : 보강된 판의 양면의 응력

(단, $f_1 \geq f_2$ 이며 압축응력을 정(+)으로 한다.)

* 인장 (하부)플랜지의 허용응력 (SM490 사용)

$$f_{ta} = 190.0 \text{ MPa}$$

* 압축 (상부)플랜지의 허용응력 (SM490 사용)

$$t_u \geq \frac{b}{24 \cdot i \cdot n} = \frac{2500}{24 \times 1.000 \times 6} = 17.4 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190.0 \text{ MPa}$$

$$\frac{b}{24 \cdot i \cdot n} > t_u \geq \frac{b}{49 \cdot i \cdot n} = \frac{2500}{49 \times 1.000 \times 6} = 8.5 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190 - 3.9 \left(\frac{b}{(t_u \cdot i \cdot n) - 24} \right) = 148.2$$

$$\frac{b}{49 \cdot i \cdot n} > t_u \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.2 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 220000 \times \left\{ (t_u \cdot i \cdot n) / b \right\} = 182.477 \text{ MPa}$$

$$\text{사용 } t_u = 12.0 \text{ mm}$$

$$\text{따라서, } f_{ca} = 148.183 \text{ MPa}$$

* 철근콘크리트의 허용응력 (도.설 3.9.3)

$$f_{ca} = 0.4 \quad f_{ck} = 10.800 \text{ MPa}$$

$$(f_{ck} = 27 \text{ MPa 사용})$$

$$f_{ta} = 0.07 \quad f_{ck} = 1.890 \text{ MPa}$$

하중조합	CONCRETE				STEEL			
	작용응력(MPa)		허용응력(MPa)		작용응력(MPa)		허용응력(MPa)	
	상 연	하 연	상 연	하 연	상 연	하 연	상 연	하 연
1			10.800	10.800	24.453	-23.974	148.183	190.000
1+2+3	1.924	1.293	10.800	10.800	34.031	-67.402	148.183	190.000
1+2+3+4	1.734	1.194	10.800	10.800	35.317	-65.603	170.410	190.000
1+2+3+4+5	0.560	0.038	10.800	10.800	45.434	-50.861	170.410	190.000
1+2+3+4+5+6	-1.003	-1.472	2.174	2.174	59.052	-32.854	192.638	218.500
1+2+3+4+5-6	2.122	1.547	12.420	12.420	31.817	-68.868	192.638	218.500

주) 압축응력을 정(+), 인장응력을 부(-)로 하였음.

허용응력의 활증 (도.설 3.9.3.1 참조)

(9) 합성응력의 검토 (도.설 3.8.2.4)

(상 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{59.052}{192.638} \right)^2 + \left(\frac{13.339}{110.000} \right)^2$$

$$= 0.094 + 0.015 = 0.109 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-67.402}{190.000} \right)^2 + \left(\frac{13.339}{110.000} \right)^2$$

$$= 0.123 + 0.015 = 0.138 < 1.2 \quad \mathbf{O.K.}$$

(10) 판의 최소두께 검토

압축(상부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = 10 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.} \quad (\text{합성형 스테드 설치})$$

인장(하부)플랜지 (☞ 도.설.기 3.8.3.1 및 3.8.3.2)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 9.9 \text{ mm} \leq t = 10 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/24.453)} = 2.787 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 3.6 \text{ mm} \leq t = 10 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/59.052)} = 1.794 > 1.2 \Rightarrow 1.200$$

(11) 항복에 대한 안전도 검사 (☞ 도.설.해(2003) 3.9.3.2)

$\Sigma f = 1.3 \times (\text{합성전 사하중 응력} + \text{합성후 사하중}) + 2.15 \times \text{활하중에 의한 응력(충격포함)}$
+ (크리프응력 변화량) + (건조수축응력변화량) + (온도차응력변화량) 의 조합 중에서
가장 불리한 하중 조합에 대하여 검토

① 바닥판 콘크리트

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.267 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 1.924 - 0.267 = 1.657 \text{ MPa}$$

$$\begin{aligned} \Sigma f &= 1.3 \times 0.267 + 2.15 \times 1.657 + (-0.19) + (-1.175) + (1.562) \\ &= 4.107 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K.} \quad (\text{크리프, 건조수축 포함시}) \end{aligned}$$

$$\begin{aligned} \Sigma f &= 1.3 \times 0.267 + 2.15 \times 1.657 + (1.562) \\ &= 5.472 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K.} \quad (\text{크리프, 건조수축 제외시}) \end{aligned}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 24.453 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 1.328 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 34.031 - 24.453 - 1.328 = 8.250 \text{ MPa}$$

$$\begin{aligned} \Sigma f &= 1.3 \times (24.453 + 1.328) + 2.15 \times 8.25 + (1.286) + (10.117) + (13.618) \\ &= 76.274 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K.} \quad (\text{크리프, 건조수축 포함시}) \end{aligned}$$

$$\begin{aligned} \Sigma f &= 1.3 \times (24.453 + 1.328) + 2.15 \times 8.25 + (13.618) \\ &= 64.871 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K.} \quad (\text{크리프, 건조수축 제외시}) \end{aligned}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -23.974 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -6.019 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -67.402 - -23.974 - -6.019 = -37.408 \text{ MPa}$$

$$\begin{aligned} \Sigma f &= 1.3 \times (-23.974 + -6.019) + 2.15 \times -37.408 + (1.799) + (14.742) + (-18.007) \\ &= -120.885 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K.} \quad (\text{크리프, 건조수축 포함시}) \end{aligned}$$

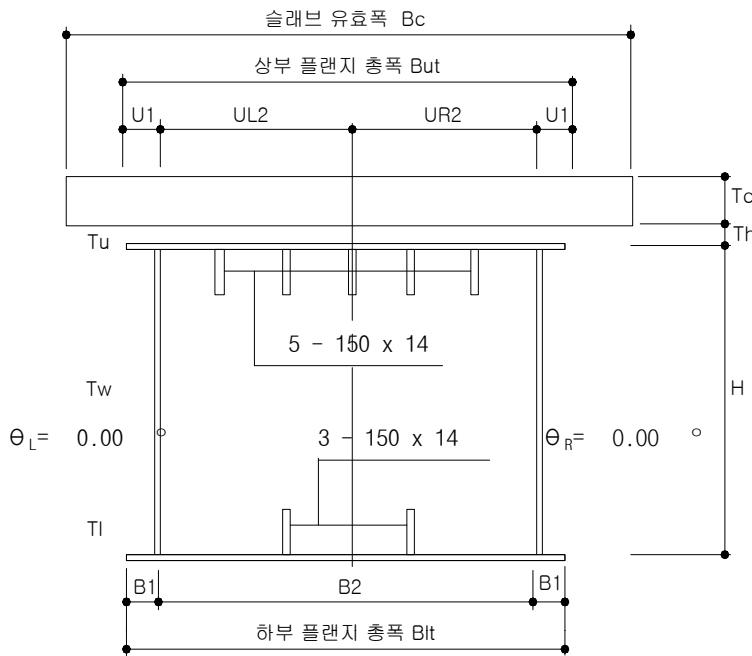
$$\begin{aligned} \Sigma f &= 1.3 \times (-23.974 + -6.019) + 2.15 \times -37.408 + (-18.007) \\ &= -137.426 \text{ MPa} < f_y = 315.0 \text{ MPa} \end{aligned}$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	4.107	16.200	0.K!!!	3.94
	크리프, 건조수축제외시	5.472	16.200	0.K!!!	2.96
상부플랜지	크리프, 건조수축 포함시	76.274	315.000	0.K!!!	4.12
	크리프, 건조수축제외시	64.871	315.000	0.K!!!	4.85
하부플랜지	크리프, 건조수축 포함시	-120.885	315.000	0.K!!!	2.60
	크리프, 건조수축제외시	-137.426	315.000	0.K!!!	2.29

5-3. 3경간 최대 정모멘트 단면검토(G1)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

$H = 2.600 \text{ m}$
 $Bc = 6.036 \text{ m}$
 $UL2 = 1.250, UR2 = 1.250 \text{ m}$
 $B2 = 2.500 \text{ m}$
 $But = 2.700, Blt = 2.700 \text{ m}$
 상하 플랜지 유효폭
 $Bue = 2.700, Ble = 2.700 \text{ m}$
 $Tc = 0.250 \text{ m}$
 $Th = 0.050 \text{ m}$
 $Tu = 0.016 \text{ m}$
 $TI = 0.022 \text{ m}$
 $Tw = 0.012 \text{ m}$
 $U1 = 0.100 \text{ m}$
 $B1 = 0.100 \text{ m}$

RIB 150 x 14 mm, 150 x 14 mm

구 분	단 위	입력 DATA
E_s : 강 의 탄성계수	MPa	210000
E_c : 콘크리트의 탄성계수	MPa	26702
ε_s : 바닥판 콘크리트의 건조수축에 의한 최종수축율		0.00018
α : 강재 및 콘크리트의 선팽창계수		0.000012
ϕ_2 : 건조수축에 의한 크리이프계수		4
n : 강과 콘크리트의 탄성계수비		8
t : 강과 콘크리트의 온도차	℃	10
M_s : 합성전 고정하중에 의한 모멘트	kN · m	13375.338
M_{sc} : 합성후 고정하중에 의한 모멘트	kN · m	3533.503
M_v : 활하중+지점침하에 의한 모멘트	kN · m	8620.970
S_s : 합성전 고정하중에 의한 전단력	kN	192.668
S_{sc} : 합성후 고정하중에 의한 전단력	kN	55.711
S_v : 활하중+지점침하에 의한 전단력	kN	373.848
M_{st} : 합성전 고정하중에 의한 비틀림모멘트	kN · m	0.000
M_{sct} : 합성후 고정하중에 의한 비틀림모멘트	kN · m	0.000
M_{vt} : 활하중+지점침하에 의한 비틀림모멘트	kN · m	313.931

< 참고 > 합성전 고정하중 : 강재자중 + 바닥판콘크리트자중

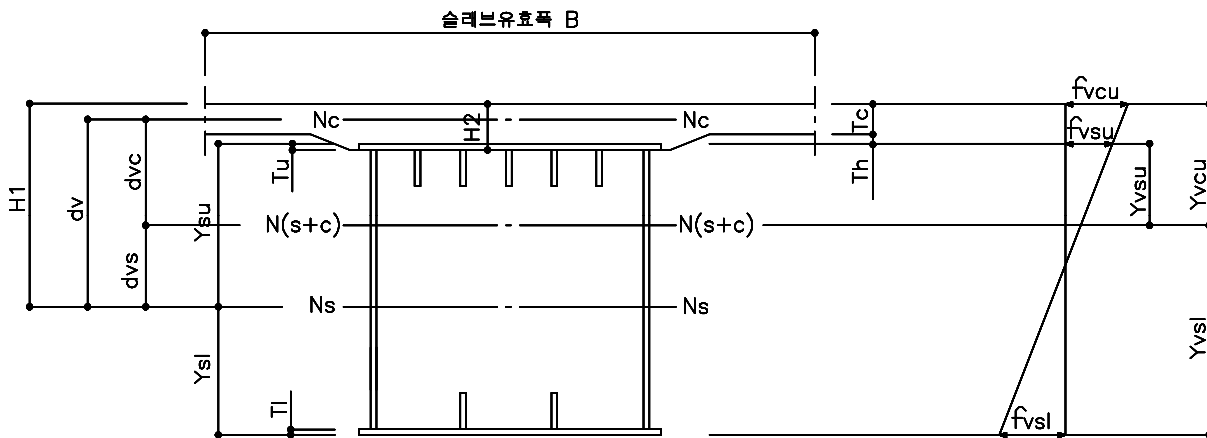
합성후 고정하중 : 방호벽 + PAVEMENT자중

단 면 제 원

단 면	B(mm)	H(mm)	A(mm ²)	Y(mm)	A*Y(mm ³)	A*Y ² (mm ⁴)	I _x (mm ⁴)
1 - UPPER FLANGE	2700.0	16.0	43200	1308.0	56505600	73909324800	921600
5 - UPPER RIB	14.0	150.0	10500	1225.0	12862500	15756562500	19687500
1 - L_WEB	12.0	2600.0	31200	0.0	0	0	17576000000
1 - R_WEB	12.0	2600.0	31200	0.0	0	0	17576000000
3 - LOWER RIB	14.0	150.0	6300	-1225.0	-7717500	9453937500	11812500
1 - LOWER FLANGE	2700.0	22.0	59400	-1311.0	-77873400	1.02092E+11	2395800
강단면 합계			181800		-16222800	2.01212E+11	35186817400
1 - RC SLAB	6036.0	250.0	1509000	1475.0	2225775000	3283018125000	7859375000

* As = 181800 mm² , Ac = 1509000 mm²

2) 응 력 검 토



(1) 합 성 전

$$I_{s'} = A_s \cdot Y^2 + \sum I_s = ##### + 35186817400.0 = 236398669600 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -16222800 / 181800 = -89.234 \text{ mm}$$

$$I_s = I_{s'} - A_s \cdot \delta s^2 = ##### - 181800 \times (-89.234)^2 = 234951039018 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2600.0 / 2 + 16.0 - (-89.234) = 1405.234 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1405.234 - 2638.000 = -1232.766 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + T_u/2 + T_l/2) = 6578928.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 79.997 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = -70.179 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 3.088 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 370425.0 \text{ mm}^2$$

$$I_{c/n} = 982421875 \text{ mm}^4$$

$$I_{c/n} = 982421875 \text{ mm}^4$$

$$767.7$$

$$\begin{aligned}
dvs &= dv - dvc = 796.5 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 892.7 \text{ mm} \\
Yvcl &= Yvcu - Tc = 642.7 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 608.7 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2029.3 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 462448199036 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6618178.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.853 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.614 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 4.651 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -15.506 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.893 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 2.080 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.498 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 11.348 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -37.830 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 7.968 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 276112.5 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1029.9 \text{ mm} & K = 0.557 \\
ds1 &= dv - dc1 = 534.3 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1154.9 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 904.9 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 870.9 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1767.1 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 387385247604 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 1106463 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 1106463 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 1139584798 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.853 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.614 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.484 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.271 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 5.434 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = 4.440 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 244675.000 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1162.3 \text{ mm}$$

$$ds2 = dv - dc2 = 402.0 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1287.3 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1037.3 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 1003.3 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1634.7 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 349588954550.6 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 2376675 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2762332105 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon_s = -0.934 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon_s = -0.980 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 14.129 \text{ MPa}$$

$$fvs12 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 2.519 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 4753350 \text{ N}$$

$$Mvt = P1 \cdot dvc = 3649179228 \text{ N} \cdot \text{mm}$$

$$fcut1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon_t = -1.110 \text{ MPa}$$

$$fclt1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon_t = -1.247 \text{ MPa}$$

$$fsut = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 15.508 \text{ MPa}$$

$$fslt = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 3.913 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 11.948 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(8) 조합응력의 검토 (도.설 3.4.2.1)

$$i = 0.65(\phi/n)^2 + 0.13(\phi/n) + 1.0$$

$$= 0.650 \times (0.0/6)^2 + 0.130 \times (0.0/6) + 1.0 = 1.000$$

$$\therefore \phi = (f_1 - f_2)/f_1 \approx 0$$

여기서, n : 종리브에 의해서 구분되는 Pannel의 수

i : 응력구배계수 ϕ : 응력구배

f_1, f_2 : 보강된 판의 양면의 응력

(단, $f_1 \geq f_2$ 이며 압축응력을 정(+)으로 한다.)

* 인장 (하부)플랜지의 허용응력 (SM490 사용)

$$f_{ta} = 190.0 \text{ MPa}$$

* 압축 (상부)플랜지의 허용응력 (SM490 사용)

$$t_u \geq \frac{b}{24 \cdot i \cdot n} = \frac{2500}{24 \times 1.000 \times 6} = 17.4 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190.0 \text{ MPa}$$

$$\frac{b}{24 \cdot i \cdot n} > t_u \geq \frac{b}{49 \cdot i \cdot n} = \frac{2500}{49 \times 1.000 \times 6} = 8.5 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190 - 3.9 \left(\frac{b}{(t_u \cdot i \cdot n) - 24} \right) = 182.0$$

$$\frac{b}{49 \cdot i \cdot n} > t_u \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.2 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 220000 \times \left\{ (t_u \cdot i \cdot n) / b \right\} = 324.403 \text{ MPa}$$

$$\text{사용 } t_u = 16.0 \text{ mm}$$

$$\text{따라서, } f_{ca} = 182.038 \text{ MPa}$$

* 철근콘크리트의 허용응력 (도.설 3.9.3)

$$f_{ca} = 0.4 \quad f_{ck} = 10.800 \text{ MPa}$$

$$(f_{ck} = 27 \text{ MPa 사용})$$

$$f_{ta} = 0.07 \quad f_{ck} = 1.890 \text{ MPa}$$

하중조합	CONCRETE				STEEL			
	작용응력(MPa)		허용응력(MPa)		작용응력(MPa)		허용응력(MPa)	
	상 연	하 연	상 연	하 연	상 연	하 연	상 연	하 연
1			10.800	10.800	79.997	-70.179	182.038	190.000
1+2+3	2.933	2.112	10.800	10.800	95.996	-123.515	182.038	190.000
1+2+3+4	2.449	1.841	10.800	10.800	101.430	-122.403	209.344	190.000
1+2+3+4+5	1.515	0.861	10.800	10.800	115.560	-119.884	209.344	190.000
1+2+3+4+5+6	0.405	-0.386	12.420	2.174	131.067	-115.971	236.649	218.500
1+2+3+4+5-6	2.624	2.108	12.420	12.420	100.052	-123.797	236.649	218.500

주) 압축응력을 정(+), 인장응력을 부(-)로 하였음.

허용응력의 활증 (도.설 3.9.3.1 참조)

(9) 합성응력의 검토 (도.설 3.8.2.4)

(상 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{131.067}{236.649} \right)^2 + \left(\frac{11.948}{110.000} \right)^2$$

$$= 0.307 + 0.012 = 0.319 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-123.515}{190.000} \right)^2 + \left(\frac{11.948}{110.000} \right)^2$$

$$= 0.422 + 0.012 = 0.434 < 1.2 \quad \mathbf{O.K.}$$

(10) 판의 최소두께 검토

압축(상부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = 10 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K. (합성형 스퍼드 설치)}$$

인장(하부)플랜지 (☞ 도.설.기 3.8.3.1 및 3.8.3.2)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 22 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 22 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 9.9 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/79.997)} = 1.541 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 4.6 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/131.067)} = 1.204 > 1.2 \Rightarrow 1.200$$

(11) 항복에 대한 안전도 검사 (☞ 도.설.해(2003) 3.9.3.2)

$\Sigma f = 1.3 \times (\text{합성전 사하중 응력} + \text{합성후 사하중}) + 2.15 \times \text{활하중에 의한 응력(충격포함)}$
 $+ (\text{크리프응력 변화량}) + (\text{건조수축응력변화량}) + (\text{온도차응력변화량})$ 의 조합 중에서
가장 불리한 하중 조합에 대하여 검토

① 바닥판 콘크리트

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.853 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 2.933 - 0.853 = 2.080 \text{ MPa}$$

$$\Sigma f = 1.3 \times 0.853 + 2.15 \times 2.08 + (-0.484) + (-0.934) + (1.11) \\ = 5.273 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times 0.853 + 2.15 \times 2.08 + (1.11) \\ = 6.691 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 79.997 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 4.651 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 95.996 - 79.997 - 4.651 = 11.348 \text{ MPa}$$

$$\Sigma f = 1.3 \times (79.997 + 4.651) + 2.15 \times 11.348 + (5.434) + (14.129) + (15.508) \\ = 169.512 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (79.997 + 4.651) + 2.15 \times 11.348 + (15.508) \\ = 149.948 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -70.179 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -15.506 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -123.515 - -70.179 - -15.506 = -37.830 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-70.179 + -15.506) + 2.15 \times -37.83 + (1.112) + (2.519) + (-3.913) \\ = -193.007 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

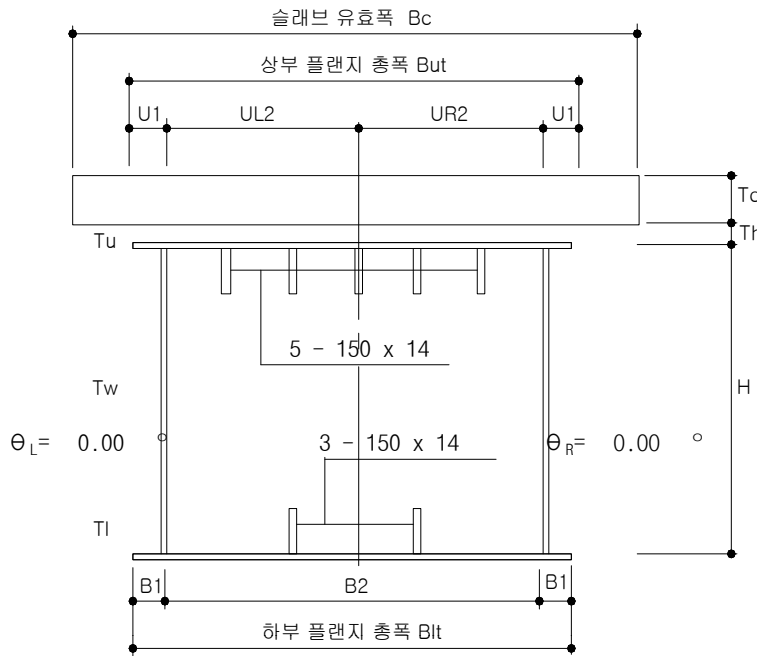
$$\Sigma f = 1.3 \times (-70.179 + -15.506) + 2.15 \times -37.83 + (-3.913) \\ = -196.638 \text{ MPa} < f_y = 315.0 \text{ MPa}$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	5.273	16.200	0.K!!!	3.07
	크리프, 건조수축제외시	6.691	16.200	0.K!!!	2.42
상부플랜지	크리프, 건조수축 포함시	169.512	315.000	0.K!!!	1.85
	크리프, 건조수축제외시	149.948	315.000	0.K!!!	2.10
하부플랜지	크리프, 건조수축 포함시	-193.007	315.000	0.K!!!	1.63
	크리프, 건조수축제외시	-196.638	315.000	0.K!!!	1.60

5-4. 1경간 최대 정모멘트 단면검토(G2)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

$H = 2.600 \text{ m}$
 $B_c = 6.046 \text{ m}$
 $UL2 = 1.250, UR2 = 1.250 \text{ m}$
 $B2 = 2.500 \text{ m}$
 $But = 2.700, Blt = 2.700 \text{ m}$
 상하 플랜지 유효폭
 $Bue = 2.700, Ble = 2.700 \text{ m}$
 $T_c = 0.250 \text{ m}$
 $Th = 0.050 \text{ m}$
 $Tu = 0.016 \text{ m}$
 $TI = 0.022 \text{ m}$
 $Tw = 0.012 \text{ m}$
 $U1 = 0.100 \text{ m}$
 $B1 = 0.100 \text{ m}$

RIB 150 x 14 mm, 150 x 14 mm

구 분	단 위	입력 DATA
E_s : 강의 탄성계수	MPa	210000
E_c : 콘크리트의 탄성계수	MPa	26702
ε_s : 바닥판 콘크리트의 건조수축에 의한 최종수축율		0.00018
α : 강재 및 콘크리트의 선팽창계수		0.000012
$\phi 2$: 건조수축에 의한 크리이프계수		4
n : 강과 콘크리트의 탄성계수비		8
t : 강과 콘크리트의 온도차	℃	10
M_s : 합성전 고정하중에 의한 모멘트	kN · m	13385.002
M_{sc} : 합성후 고정하중에 의한 모멘트	kN · m	3311.147
M_v : 활하중+지점침하에 의한 모멘트	kN · m	7835.280
S_s : 합성전 고정하중에 의한 전단력	kN	79.427
S_{sc} : 합성후 고정하중에 의한 전단력	kN	18.002
S_v : 활하중+지점침하에 의한 전단력	kN	345.250
M_{st} : 합성전 고정하중에 의한 비틀림모멘트	kN · m	0.649
M_{sct} : 합성후 고정하중에 의한 비틀림모멘트	kN · m	5.226
M_{vt} : 활하중+지점침하에 의한 비틀림모멘트	kN · m	555.636

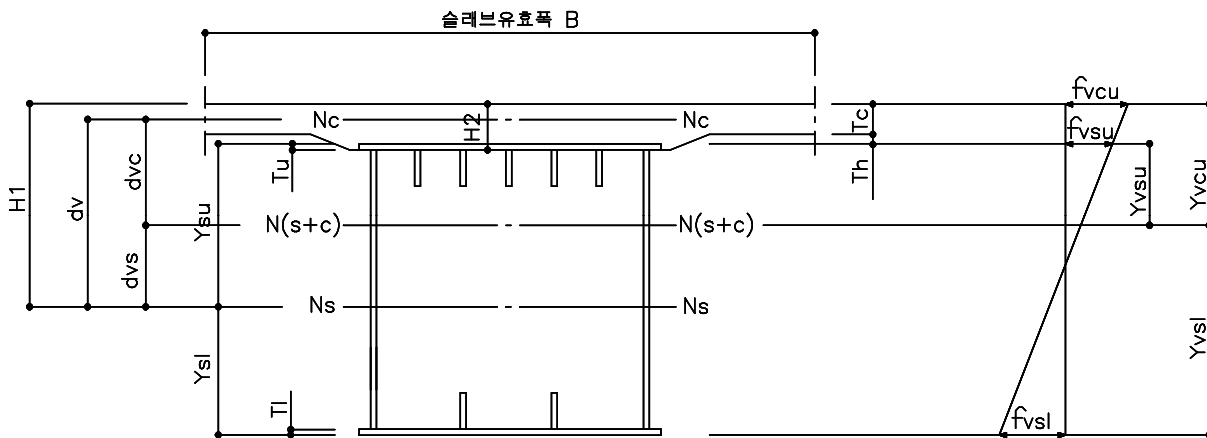
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
 합성후 고정하중 : 방호벽 + PAVEMENT자중

단 면 제 원

단 면	B(mm)	H(mm)	A(mm ²)	Y(mm)	A*Y(mm ³)	A*Y2(mm ⁴)	Ix(mm ⁴)
1 - UPPER FLANGE	2700.0	16.0	43200	1308.0	56505600	73909324800	921600
5 - UPPER RIB	14.0	150.0	10500	1225.0	12862500	15756562500	19687500
1 - L_WEB	12.0	2600.0	31200	0.0	0	0	17576000000
1 - R_WEB	12.0	2600.0	31200	0.0	0	0	17576000000
3 - LOWER RIB	14.0	150.0	6300	-1225.0	-7717500	9453937500	11812500
1 - LOWER FLANGE	2700.0	22.0	59400	-1311.0	-77873400	1.02092E+11	2395800
강단면 합계			181800		-16222800	2.01212E+11	35186817400
1 - RC SLAB	6046.0	250.0	1511500	1475.0	2229462500	3288457187500	7872395833

* As = 181800 mm² , Ac = 1511500 mm²

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = \text{#####} + 35186817400.0 = 236398669600 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -16222800 / 181800 = -89.234 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = \text{#####} - 181800 \times (-89.234)^2 = 234951039018 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2600.0 / 2 + 16.0 - (-89.234) = 1405.234 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1405.234 - 2638.000 = -1232.766 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6578928.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 80.055 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = -70.230 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 1.277 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 370737.5 \text{ mm}^2$$

$$I_c/n = 984049479 \text{ mm}^4$$

$$I_{cs} = I_c/n + A_v \cdot Y_{cs}^2 = 1524120000 \text{ mm}^4$$

$$767.1$$

$$\begin{aligned}
dvs &= dv - dvc = 797.2 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 892.1 \text{ mm} \\
Yvcl &= Yvcu - Tc = 642.1 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 608.1 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2029.9 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 462633850695 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6618178.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.798 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.574 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 4.352 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -14.529 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.321 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 1.889 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.359 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 10.298 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -34.380 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 9.031 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 276268.8 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1029.4 \text{ mm} & K = 0.557 \\
ds1 &= dv - dc1 = 534.9 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1154.4 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 904.4 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 870.4 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1767.6 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 387551712221 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 1037262 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 1037262 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 1067707566 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.798 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.574 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.453 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.253 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 5.090 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = 4.840 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 244779.167 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1161.8 \text{ mm}$$

$$ds2 = dv - dc2 = 402.5 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1286.8 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1036.8 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 1002.8 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1635.2 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 349730152384.3 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 2380613 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2765731065 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon_s = -0.934 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon_s = -0.979 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 14.143 \text{ MPa}$$

$$fvsl2 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 2.523 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 4761225 \text{ N}$$

$$Mvt = P1 \cdot dvc = 3652143878 \text{ N} \cdot \text{mm}$$

$$fcut1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon_t = -1.109 \text{ MPa}$$

$$fclt1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon_t = -1.246 \text{ MPa}$$

$$fsut1 = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 15.516 \text{ MPa}$$

$$fslt1 = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 3.917 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 10.629 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(8) 조합응력의 검토 (도.설 3.4.2.1)

$$i = 0.65(\phi/n)^2 + 0.13(\phi/n) + 1.0$$

$$= 0.650 \times (0.0 / 6)^2 + 0.130 \times (0.0 / 6) + 1.0 = 1.000$$

$$\therefore \phi = (f_1 - f_2)/f_1 \approx 0$$

여기서, n : 종리브에 의해서 구분되는 Pannel의 수

i : 응력구배계수 ϕ : 응력구배

f_1, f_2 : 보강된 판의 양면의 응력

(단, $f_1 \geq f_2$ 이며 압축응력을 정(+)으로 한다.)

* 인장 (하부)플랜지의 허용응력 (SM490 사용)

$$f_{ta} = 190.0 \text{ MPa}$$

* 압축 (상부)플랜지의 허용응력 (SM490 사용)

$$t_u \geq \frac{b}{24 \cdot i \cdot n} = \frac{2500}{24 \times 1.000 \times 6} = 17.4 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190.0 \text{ MPa}$$

$$\frac{b}{24 \cdot i \cdot n} > t_u \geq \frac{b}{49 \cdot i \cdot n} = \frac{2500}{49 \times 1.000 \times 6} = 8.5 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190 - 3.9 \left(\frac{b}{(t_u \cdot i \cdot n) - 24} \right) = 182.0$$

$$\frac{b}{49 \cdot i \cdot n} > t_u \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.2 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 220000 \times \left\{ (t_u \cdot i \cdot n) / b \right\} = 324.403 \text{ MPa}$$

$$\text{사용 } t_u = 16.0 \text{ mm}$$

$$\text{따라서, } f_{ca} = 182.038 \text{ MPa}$$

* 철근콘크리트의 허용응력 (도.설 3.9.3)

$$f_{ca} = 0.4 \quad f_{ck} = 10.800 \text{ MPa}$$

$$(f_{ck} = 27 \text{ MPa 사용})$$

$$f_{ta} = 0.07 \quad f_{ck} = 1.890 \text{ MPa}$$

하중조합	CONCRETE				STEEL			
	작용응력(MPa)		허용응력(MPa)		작용응력(MPa)		허용응력(MPa)	
	상 연	하 연	상 연	하 연	상 연	하 연	상 연	하 연
1			10.800	10.800	80.055	-70.230	182.038	190.000
1+2+3	2.687	1.934	10.800	10.800	94.705	-119.138	182.038	190.000
1+2+3+4	2.234	1.681	10.800	10.800	99.796	-118.096	209.344	190.000
1+2+3+4+5	1.300	0.701	10.800	10.800	113.938	-115.573	209.344	190.000
1+2+3+4+5+6	0.192	-0.545	12.420	2.174	129.455	-111.657	236.649	218.500
1+2+3+4+5-6	2.409	1.947	12.420	12.420	98.422	-119.490	236.649	218.500

주) 압축응력을 정(+), 인장응력을 부(-)로 하였음.

허용응력의 활증 (도.설 3.9.3.1 참조)

(9) 합성응력의 검토 (도.설 3.8.2.4)

(상 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{129.455}{236.649} \right)^2 + \left(\frac{10.629}{110.000} \right)^2$$

$$= 0.299 + 0.009 = 0.309 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-119.138}{190.000} \right)^2 + \left(\frac{10.629}{110.000} \right)^2$$

$$= 0.377 + 0.009 = 0.386 < 1.2 \quad \mathbf{O.K.}$$

(10) 판의 최소두께 검토

압축(상부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = 10 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K. (합성형 스테드 설치)}$$

인장(하부)플랜지 (☞ 도.설.기 3.8.3.1 및 3.8.3.2)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 22 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 22 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 9.9 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/80.055)} = 1.541 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 4.6 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/129.455)} = 1.211 > 1.2 \Rightarrow 1.200$$

(11) 항복에 대한 안전도 검사 (☞ 도.설.해(2003) 3.9.3.2)

$\Sigma f = 1.3 \times (\text{합성전 사하중 응력} + \text{합성후 사하중}) + 2.15 \times \text{활하중에 의한 응력(충격포함)}$
 $+ (\text{크리프응력 변화량}) + (\text{건조수축응력변화량}) + (\text{온도차응력변화량})$ 의 조합 중에서
 가장 불리한 하중 조합에 대하여 검토

① 바닥판 콘크리트

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.798 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 2.687 - 0.798 = 1.889 \text{ MPa}$$

$$\Sigma f = 1.3 \times 0.798 + 2.15 \times 1.889 + (-0.453) + (-0.934) + (1.109) \\ = 4.820 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times 0.798 + 2.15 \times 1.889 + (1.109) \\ = 6.206 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 80.055 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 4.352 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 94.705 - 80.055 - 4.352 = 10.298 \text{ MPa}$$

$$\Sigma f = 1.3 \times (80.055 + 4.352) + 2.15 \times 10.298 + (5.09) + (14.143) + (15.516) \\ = 166.620 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (80.055 + 4.352) + 2.15 \times 10.298 + (15.516) \\ = 147.387 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -70.230 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -14.529 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -119.138 - -70.23 - -14.529 = -34.379 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-70.23 + -14.529) + 2.15 \times -34.379 + (1.042) + (2.523) + (-3.917) \\ = -184.454 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (-70.23 + -14.529) + 2.15 \times -34.379 + (-3.917) \\ = -188.019 \text{ MPa} < 315.0$$

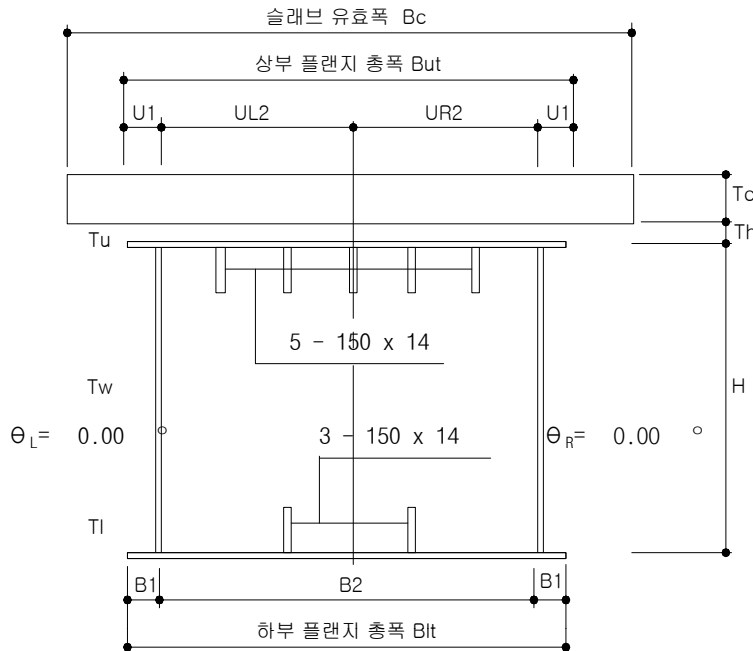
- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	4.820	16.200	0.K!!!	3.36
	크리프, 건조수축제외시	6.206	16.200	0.K!!!	2.61
상부플랜지	크리프, 건조수축 포함시	166.620	315.000	0.K!!!	1.89
	크리프, 건조수축제외시	147.387	315.000	0.K!!!	2.13
하부플랜지	크리프, 건조수축 포함시	-184.454	315.000	0.K!!!	1.70
	크리프, 건조수축제외시	-188.019	315.000	0.K!!!	1.67

5-5. 2경간 최대 정모멘트 단면검토(G2)

1) 단면가정 및 설계조건

주부재사용강종 = SM490


$$H = 2.600 \text{ m}$$
$$B_C = 5.951 \text{ m}$$

UL2= 1.250 , UR2= 1.250 m

$$B2 = 2.500 \text{ m}$$

But= 2.700 , Blt= 2.700 m

상하 플랜지 유효폭

Bue= 2.700 , Ble= 2.700 m

$$T_C = 0.250 \text{ m}$$
$$T_h = 0.050 \text{ m}$$
$$T_u = 0.012 \text{ m}$$
$$Tl = 0.014 \text{ m}$$
$$T_W = 0.010 \text{ m}$$
$$U1 = 0.100 \text{ m}$$
$$B1 = 0.100 \text{ m}$$

RIB 150 x 14 mm , 150 x 14 mm

구 분	단 위	입력 DATA
E_s : 강의 탄성계수	MPa	210000
E_c : 콘크리트의 탄성계수	MPa	26702
ϵ_s : 바닥판 콘크리트의 건조수축에 의한 최종수축율		0.00018
α : 강재 및 콘크리트의 선팽창계수		0.000012
ϕ_2 : 건조수축에 의한 크리이프계수		4
n : 강과 콘크리트의 탄성계수비		8
t : 강과 콘크리트의 온도차	℃	10
M_s : 합성전 고정하중에 의한 모멘트	kN · m	3219.428
M_{sc} : 합성후 고정하중에 의한 모멘트	kN · m	830.715
M_v : 활하중+지점침하에 의한 모멘트	kN · m	5553.970
S_s : 합성전 고정하중에 의한 전단력	kN	134.345
S_{sc} : 합성후 고정하중에 의한 전단력	kN	34.175
S_v : 활하중+지점침하에 의한 전단력	kN	404.817
M_{st} : 합성전 고정하중에 의한 비틀림모멘트	kN · m	0.000
M_{sct} : 합성후 고정하중에 의한 비틀림모멘트	kN · m	0.000
M_{vt} : 활하중+지점침하에 의한 비틀림모멘트	kN · m	533.017

< 참고 > 합성전 고정하중 : 강재자중 + 바닥판콘크리트자중

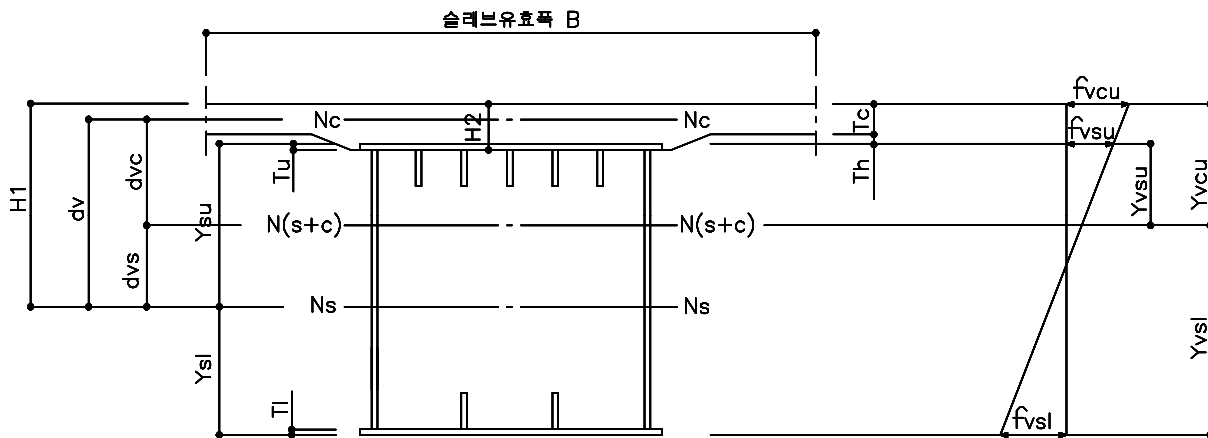
합성후 고정하중 : 방호벽 + PAVEMENT자중

단 면 제 원

단 면	B(mm)	H(mm)	A(mm ²)	Y(mm)	A*Y(mm ³)	A*Y ² (mm ⁴)	I _x (mm ⁴)
1 - UPPER FLANGE	2700.0	12.0	32400	1306.0	42314400	55262606400	388800
5 - UPPER RIB	14.0	150.0	10500	1225.0	12862500	15756562500	19687500
1 - L_WEB	10.0	2600.0	26000	0.0	0	0	14646666667
1 - R_WEB	10.0	2600.0	26000	0.0	0	0	14646666667
3 - LOWER RIB	14.0	150.0	6300	-1225.0	-7717500	9453937500	11812500
1 - LOWER FLANGE	2700.0	14.0	37800	-1307.0	-49404600	64571812200	617400
강단면 합계			139000		-1945200	1.45045E+11	29325839533
1 - RC SLAB	5951.0	250.0	1487750	1475.0	2194431250	3236786093750	7748697917

* As = 139000 mm² , Ac = 1487750 mm²

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = \text{#####} + 29325839533.3 = 174370758133 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -1945200 / 139000 = -13.994 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = \text{#####} - 139000 \times (-13.994)^2 = 174343536529 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2600.0 / 2 + 12.0 - (-13.994) = 1325.994 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1325.994 - 2626.000 = -1300.006 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6558630.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 24.486 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = -24.006 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 2.584 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 324968.8 \text{ mm}^2$$

$$I_c/n = 968587240 \text{ mm}^4$$

$$I_c/n = 968587240 \text{ mm}^4$$

$$\begin{aligned}
dvs &= dv - dvc = 852.1 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 761.9 \text{ mm} \\
Yvcl &= Yvcu - Tc = 511.9 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 473.9 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2152.1 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 351671766545 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6597848.8 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.225 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.151 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 1.119 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -5.084 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.657 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 1.504 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.011 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 7.484 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -33.988 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 11.824 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 231984.4 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 892.2 \text{ mm} & K = -0.197 \\
ds1 &= dv - dc1 = 596.8 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1017.2 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 767.2 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 729.2 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1896.8 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 298352038759 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 279783 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 279783 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 249614509 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.225 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.151 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.160 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.084 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 1.086 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = -4.540 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 200989.583 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1029.8 \text{ mm}$$

$$ds2 = dv - dc2 = 459.2 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1154.8 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 904.8 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 866.8 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1759.2 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 269715060524.4 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 2343206 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2412930353 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon_s = -1.174 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon_s = -1.156 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 10.131 \text{ MPa}$$

$$fvsl2 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 14.759 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 4686413 \text{ N}$$

$$Mvt = P1 \cdot dvc = 2984741556 \text{ N} \cdot \text{mm}$$

$$fcut1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon_t = -1.561 \text{ MPa}$$

$$fclt1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon_t = -1.509 \text{ MPa}$$

$$fsut1 = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 13.629 \text{ MPa}$$

$$fslt1 = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 18.019 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 15.065 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(8) 조합응력의 검토 (도.설 3.4.2.1)

$$i = 0.65(\phi/n)^2 + 0.13(\phi/n) + 1.0$$

$$= 0.650 \times (0.0/6)^2 + 0.130 \times (0.0/6) + 1.0 = 1.000$$

$$\therefore \phi = (f_1 - f_2)/f_1 \approx 0$$

여기서, n : 종리브에 의해서 구분되는 Pannel의 수

i : 응력구배계수 ϕ : 응력구배

f_1, f_2 : 보강된 판의 양면의 응력

(단, $f_1 \geq f_2$ 이며 압축응력을 정(+)으로 한다.)

* 인장 (하부)플랜지의 허용응력 (SM490 사용)

$$f_{ta} = 190.0 \text{ MPa}$$

* 압축 (상부)플랜지의 허용응력 (SM490 사용)

$$t_u \geq \frac{b}{24 \cdot i \cdot n} = \frac{2500}{24 \times 1.000 \times 6} = 17.4 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190.0 \text{ MPa}$$

$$\frac{b}{24 \cdot i \cdot n} > t_u \geq \frac{b}{49 \cdot i \cdot n} = \frac{2500}{49 \times 1.000 \times 6} = 8.5 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190 - 3.9 \left(\frac{b}{(t_u \cdot i \cdot n) - 24} \right) = 148.2$$

$$\frac{b}{49 \cdot i \cdot n} > t_u \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.2 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 220000 \times \left\{ (t_u \cdot i \cdot n) / b \right\} = 182.477 \text{ MPa}$$

$$\text{사용 } t_u = 12.0 \text{ mm}$$

$$\text{따라서, } f_{ca} = 148.183 \text{ MPa}$$

* 철근콘크리트의 허용응력 (도.설 3.9.3)

$$f_{ca} = 0.4 \quad f_{ck} = 10.800 \text{ MPa}$$

$$(f_{ck} = 27 \text{ MPa 사용})$$

$$f_{ta} = 0.07 \quad f_{ck} = 1.890 \text{ MPa}$$

하중조합	CONCRETE				STEEL			
	작용응력(MPa)		허용응력(MPa)		작용응력(MPa)		허용응력(MPa)	
	상 연	하 연	상 연	하 연	상 연	하 연	상 연	하 연
1			10.800	10.800	24.486	-24.006	148.183	190.000
1+2+3	1.729	1.162	10.800	10.800	33.089	-63.078	148.183	190.000
1+2+3+4	1.569	1.078	10.800	10.800	34.175	-61.559	170.410	190.000
1+2+3+4+5	0.395	-0.078	10.800	1.890	44.306	-46.800	170.410	190.000
1+2+3+4+5+6	-1.166	-1.586	2.174	2.174	57.935	-28.781	192.638	218.500
1+2+3+4+5-6	1.956	1.431	12.420	12.420	30.677	-64.820	192.638	218.500

주) 압축응력을 정(+), 인장응력을 부(-)로 하였음.

허용응력의 활증 (도.설 3.9.3.1 참조)

(9) 합성응력의 검토 (도.설 3.8.2.4)

(상 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{57.935}{192.638} \right)^2 + \left(\frac{15.065}{110.000} \right)^2$$

$$= 0.090 + 0.019 = 0.109 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-63.078}{190.000} \right)^2 + \left(\frac{15.065}{110.000} \right)^2$$

$$= 0.110 + 0.019 = 0.129 < 1.2 \quad \mathbf{O.K.}$$

(10) 판의 최소두께 검토

압축(상부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = 10 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.} \quad (\text{합성형 스테드 설치})$$

인장(하부)플랜지 (☞ 도.설.기 3.8.3.1 및 3.8.3.2)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 9.9 \text{ mm} \leq t = 10 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/24.486)} = 2.786 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 3.6 \text{ mm} \leq t = 10 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/57.935)} = 1.811 > 1.2 \Rightarrow 1.200$$

(11) 항복에 대한 안전도 검사 (☞ 도.설.해(2003) 3.9.3.2)

$\Sigma f = 1.3 \times (\text{합성전 사하중 응력} + \text{합성후 사하중}) + 2.15 \times \text{활하중에 의한 응력(충격포함)}$
 $+ (\text{크리프응력 변화량}) + (\text{건조수축응력변화량}) + (\text{온도차응력변화량})$ 의 조합 중에서
 가장 불리한 하중 조합에 대하여 검토

① 바닥판 콘크리트

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.225 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 1.729 - 0.225 = 1.504 \text{ MPa}$$

$$\Sigma f = 1.3 \times 0.225 + 2.15 \times 1.504 + (-0.16) + (-1.174) + (1.561) = 3.753 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K.} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times 0.225 + 2.15 \times 1.504 + (1.561) = 5.087 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K.} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 24.486 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 1.119 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 33.089 - 24.486 - 1.119 = 7.484 \text{ MPa}$$

$$\Sigma f = 1.3 \times (24.486 + 1.119) + 2.15 \times 7.484 + (1.086) + (10.131) + (13.629) = 74.223 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K.} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (24.486 + 1.119) + 2.15 \times 7.484 + (13.629) = 63.006 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K.} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -24.006 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -5.084 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -63.078 - -24.006 - -5.084 = -33.988 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-24.006 + -5.084) + 2.15 \times -33.988 + (1.519) + (14.759) + (-18.019) = -112.633 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K.} \quad (\text{크리프, 건조수축 포함시})$$

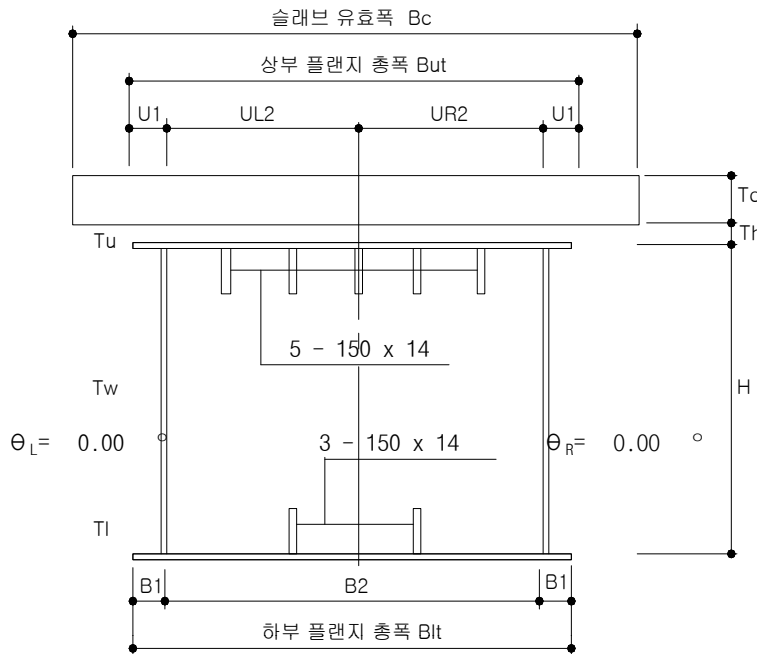
$$\Sigma f = 1.3 \times (-24.006 + -5.084) + 2.15 \times -33.988 + (-18.019) = -128.911 \text{ MPa} < f_y = 315.0 \text{ MPa}$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	3.753	16.200	0.K!!!	4.31
	크리프, 건조수축제외시	5.087	16.200	0.K!!!	3.18
상부플랜지	크리프, 건조수축 포함시	74.223	315.000	0.K!!!	4.24
	크리프, 건조수축제외시	63.006	315.000	0.K!!!	4.99
하부플랜지	크리프, 건조수축 포함시	-112.633	315.000	0.K!!!	2.79
	크리프, 건조수축제외시	-128.911	315.000	0.K!!!	2.44

5-6. 3경간 최대 정모멘트 단면검토(G2)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.600 m

Bc = 6.046 m

UL2= 1.250 , UR2= 1.250 m

B2 = 2.500 m

But= 2.700 , Blt= 2.700 m

상하 플랜지 유효폭

Bue= 2.700 , Ble= 2.700 m

Tc = 0.250 m

Th = 0.050 m

Tu = 0.016 m

TI = 0.022 m

Tw = 0.012 m

U1 = 0.100 m

B1 = 0.100 m

RIB 150 x 14 mm , 150 x 14 mm

구 분	단 위	입력 DATA
Es : 강의 탄성계수	MPa	210000
Ec : 콘크리트의 탄성계수	MPa	26702
εs : 바닥판 콘크리트의 건조수축에의한 최종수축율		0.00018
α : 강재 및 콘크리트의 선팽창계수		0.000012
φ2: 건조수축에의한 크리이프계수		4
n : 강과 콘크리트의 탄성계수비		8
t : 강과 콘크리트의 온도차	℃	10
Ms : 합성전 고정하중에의한 모멘트	kN · m	13385.002
Msc : 합성후 고정하중에의한 모멘트	kN · m	3311.147
Mv : 활하중+지점침하에의한 모멘트	kN · m	7835.279
Ss : 합성전 고정하중에의한 전단력	kN	192.904
Ssc : 합성후 고정하중에의한 전단력	kN	47.272
Sv : 활하중+지점침하에의한 전단력	kN	363.068
Mst : 합성전 고정하중에의한 비틀림모멘트	kN · m	0.000
Mstc : 합성후 고정하중에의한 비틀림모멘트	kN · m	0.000
Mvt : 활하중+지점침하에의한 비틀림모멘트	kN · m	548.705

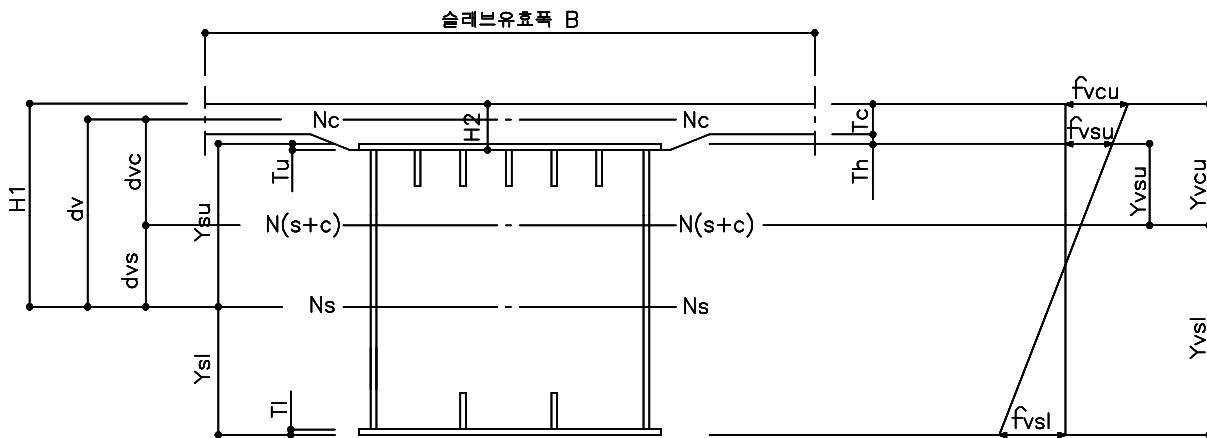
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

단 면 제 원

단 면	B(mm)	H(mm)	A(mm ²)	Y(mm)	A*Y(mm ³)	A*Y2(mm ⁴)	I _x (mm ⁴)
1 - UPPER FLANGE	2700.0	16.0	43200	1308.0	56505600	73909324800	921600
5 - UPPER RIB	14.0	150.0	10500	1225.0	12862500	15756562500	19687500
1 - L_WEB	12.0	2600.0	31200	0.0	0	0	17576000000
1 - R_WEB	12.0	2600.0	31200	0.0	0	0	17576000000
3 - LOWER RIB	14.0	150.0	6300	-1225.0	-7717500	9453937500	11812500
1 - LOWER FLANGE	2700.0	22.0	59400	-1311.0	-77873400	1.02092E+11	2395800
강단면 합계			181800		-16222800	2.01212E+11	35186817400
1 - RC SLAB	6046.0	250.0	1511500	1475.0	2229462500	3288457187500	7872395833

* As = 181800 mm² , Ac = 1511500 mm²

2) 응 력 검 토



(1) 합 성 전

$$I_{s'} = A_s \cdot Y^2 + \sum I_s = \text{#####} + 35186817400.0 = 236398669600 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -16222800 / 181800 = -89.234 \text{ mm}$$

$$I_s = I_{s'} - A_s \cdot \delta s^2 = \text{#####} - 181800 \times (-89.234)^2 = 234951039018 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2600.0 / 2 + 16.0 - (-89.234) = 1405.234 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1405.234 - 2638.000 = -1232.766 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6578928.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 80.055 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = -70.230 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 3.091 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 370737.5 \text{ mm}^2$$

$$I_{c/n} = 984049479 \text{ mm}^4$$

$$I_{c/n} = 984049479 \text{ mm}^4$$

$$\begin{aligned}
dvs &= dv - dvc = 797.2 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 892.1 \text{ mm} \\
Yvcl &= Yvcu - Tc = 642.1 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 608.1 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2029.9 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 462633850695 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6618178.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.798 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.574 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 4.352 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -14.529 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.758 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 1.889 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.359 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 10.298 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -34.380 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 9.273 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 276268.8 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1029.4 \text{ mm} & K = 0.557 \\
ds1 &= dv - dc1 = 534.9 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1154.4 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 904.4 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 870.4 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1767.6 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 387551712221 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 1037262 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 1037262 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 1067707566 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.798 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.574 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.453 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.253 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 5.090 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = 4.840 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 244779.167 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1161.8 \text{ mm}$$

$$ds2 = dv - dc2 = 402.5 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1286.8 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1036.8 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 1002.8 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1635.2 \text{ mm}$$

$$lv2 = ls + lc/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 349730152384.3 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 2380613 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2765731065 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/lv2) - Ec2 \cdot \epsilon_s = -0.934 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/lv2) - Ec2 \cdot \epsilon_s = -0.979 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/lv2 = 14.143 \text{ MPa}$$

$$fvsl2 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/lv2 = 2.523 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 4761225 \text{ N}$$

$$Mvt = P1 \cdot dvc = 3652143878 \text{ N} \cdot \text{mm}$$

$$fcut1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/lv) - Ec \cdot \epsilon_t = -1.109 \text{ MPa}$$

$$fclt1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/lv) - Ec \cdot \epsilon_t = -1.246 \text{ MPa}$$

$$fsut1 = P1/Av + k \cdot Mvt \cdot Yvsu/lv = 15.516 \text{ MPa}$$

$$fslt1 = P1/Av + k \cdot Mvt \cdot Yvsl/lv = 3.917 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 13.122 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(8) 조합응력의 검토 (도.설 3.4.2.1)

$$i = 0.65(\phi/n)^2 + 0.13(\phi/n) + 1.0$$

$$= 0.650 \times (0.0/6)^2 + 0.130 \times (0.0/6) + 1.0 = 1.000$$

$$\therefore \phi = (f_1 - f_2)/f_1 \approx 0$$

여기서, n : 종리브에 의해서 구분되는 Pannel의 수

i : 응력구배계수 ϕ : 응력구배

f_1, f_2 : 보강된 판의 양면의 응력

(단, $f_1 \geq f_2$ 이며 압축응력을 정(+)으로 한다.)

* 인장 (하부)플랜지의 허용응력 (SM490 사용)

$$f_{ta} = 190.0 \text{ MPa}$$

* 압축 (상부)플랜지의 허용응력 (SM490 사용)

$$t_u \geq \frac{b}{24 \cdot i \cdot n} = \frac{2500}{24 \times 1.000 \times 6} = 17.4 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190.0 \text{ MPa}$$

$$\frac{b}{24 \cdot i \cdot n} > t_u \geq \frac{b}{49 \cdot i \cdot n} = \frac{2500}{49 \times 1.000 \times 6} = 8.5 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 190 - 3.9 \left(\frac{b}{(t_u \cdot i \cdot n) - 24} \right) = 182.0$$

$$\frac{b}{49 \cdot i \cdot n} > t_u \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.2 \text{ mm}$$

$$\text{인 경우 : } f_{ca} = 220000 \times \left\{ (t_u \cdot i \cdot n) / b \right\} = 324.403 \text{ MPa}$$

$$\text{사용 } t_u = 16.0 \text{ mm}$$

$$\text{따라서, } f_{ca} = 182.038 \text{ MPa}$$

* 철근콘크리트의 허용응력 (도.설 3.9.3)

$$f_{ca} = 0.4 \quad f_{ck} = 10.800 \text{ MPa}$$

$$(f_{ck} = 27 \text{ MPa 사용})$$

$$f_{ta} = 0.07 \quad f_{ck} = 1.890 \text{ MPa}$$

하중조합	CONCRETE				STEEL			
	작용응력(MPa)		허용응력(MPa)		작용응력(MPa)		허용응력(MPa)	
	상 연	하 연	상 연	하 연	상 연	하 연	상 연	하 연
1			10.800	10.800	80.055	-70.230	182.038	190.000
1+2+3	2.687	1.934	10.800	10.800	94.705	-119.138	182.038	190.000
1+2+3+4	2.234	1.681	10.800	10.800	99.796	-118.096	209.344	190.000
1+2+3+4+5	1.300	0.701	10.800	10.800	113.938	-115.573	209.344	190.000
1+2+3+4+5+6	0.192	-0.545	12.420	2.174	129.455	-111.657	236.649	218.500
1+2+3+4+5-6	2.409	1.947	12.420	12.420	98.422	-119.490	236.649	218.500

주) 압축응력을 정(+), 인장응력을 부(-)로 하였음.

허용응력의 활증 (도.설 3.9.3.1 참조)

(9) 합성응력의 검토 (도.설 3.8.2.4)

(상 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{129.455}{236.649} \right)^2 + \left(\frac{13.122}{110.000} \right)^2$$

$$= 0.299 + 0.014 = 0.313 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-119.138}{190.000} \right)^2 + \left(\frac{13.122}{110.000} \right)^2$$

$$= 0.377 + 0.014 = 0.392 < 1.2 \quad \mathbf{O.K.}$$

(10) 판의 최소두께 검토

압축(상부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = 10 \text{ mm} \leq t = 16 \text{ mm} \quad \text{O.K. (합성형 스퍼드 설치)}$$

인장(하부)플랜지 (☞ 도.설.기 3.8.3.1 및 3.8.3.2)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 22 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 22 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 9.9 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/80.055)} = 1.541 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 4.6 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/129.455)} = 1.211 > 1.2 \Rightarrow 1.200$$

(11) 항복에 대한 안전도 검사 (☞ 도.설.해(2003) 3.9.3.2)

$\Sigma f = 1.3 \times (\text{합성전 사하중 응력} + \text{합성후 사하중}) + 2.15 \times \text{활하중에 의한 응력(충격포함)}$
 $+ (\text{크리프응력 변화량}) + (\text{건조수축응력변화량}) + (\text{온도차응력변화량})$ 의 조합 중에서
 가장 불리한 하중 조합에 대하여 검토

① 바닥판 콘크리트

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.798 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 2.687 - 0.798 = 1.889 \text{ MPa}$$

$$\begin{aligned} \Sigma f &= 1.3 \times 0.798 + 2.15 \times 1.889 + (-0.453) + (-0.934) + (1.109) \\ &= 4.820 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)} \end{aligned}$$

$$\begin{aligned} \Sigma f &= 1.3 \times 0.798 + 2.15 \times 1.889 + (1.109) \\ &= 6.206 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)} \end{aligned}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 80.055 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 4.352 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 94.705 - 80.055 - 4.352 = 10.298 \text{ MPa}$$

$$\begin{aligned} \Sigma f &= 1.3 \times (80.055 + 4.352) + 2.15 \times 10.298 + (5.09) + (14.143) + (15.516) \\ &= 166.620 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)} \end{aligned}$$

$$\begin{aligned} \Sigma f &= 1.3 \times (80.055 + 4.352) + 2.15 \times 10.298 + (15.516) \\ &= 147.387 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)} \end{aligned}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -70.230 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -14.529 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -119.138 - -70.23 - -14.529 = -34.379 \text{ MPa}$$

$$\begin{aligned} \Sigma f &= 1.3 \times (-70.23 + -14.529) + 2.15 \times -34.379 + (1.042) + (2.523) + (-3.917) \\ &= -184.454 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)} \end{aligned}$$

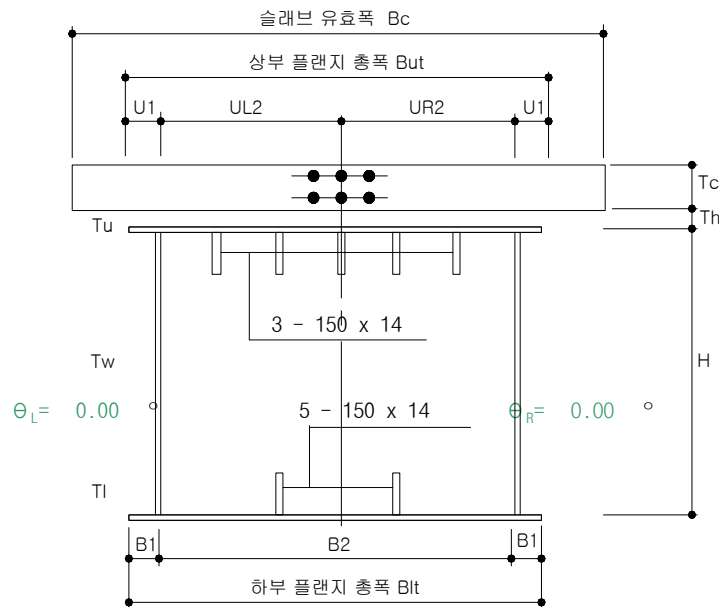
$$\begin{aligned} \Sigma f &= 1.3 \times (-70.23 + -14.529) + 2.15 \times -34.379 + (-3.917) \\ &= -188.019 \text{ MPa} < 315.0 \end{aligned}$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	4.820	16.200	0.K!!!	3.36
	크리프, 건조수축제외시	6.206	16.200	0.K!!!	2.61
상부플랜지	크리프, 건조수축 포함시	166.620	315.000	0.K!!!	1.89
	크리프, 건조수축제외시	147.387	315.000	0.K!!!	2.13
하부플랜지	크리프, 건조수축 포함시	-184.454	315.000	0.K!!!	1.70
	크리프, 건조수축제외시	-188.019	315.000	0.K!!!	1.67

5-7. 1경간 최대 부모멘트 단면검토(G1)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.600 m

Bc = 5.145 m

UL2= 1.250 , UR2= 1.250 m

B2 = 2.500 m

But= 2.700 , Blt= 2.700 m

상하 플랜지 유효폭

Bue= 2.432 , Ble= 2.432 m

Tc = 0.250 m

Th = 0.050 m

Tu = 0.028 m

Tl = 0.028 m

Tw = 0.012 m

U1 = 0.100 m

B1 = 0.100 m

RIB 150 x 14 mm , 150 x 14 mm

구 분	단 위	입력 DATA
Es : 강의 탄성계수	MPa	210000
Ec : 콘크리트의 탄성계수	MPa	26702
ϵ_s : 바닥판 콘크리트의 건조수축에 의한 최종수축율		0.00018
α : 강재 및 콘크리트의 선팽창계수		0.000012
ϕ_2 : 건조수축에 의한 크리이프계수		4
n : 강과 콘크리트의 탄성계수비		8
t : 강과 콘크리트의 온도차	°C	10
Ms : 합성전 고정하중에 의한 모멘트	kN · m	-18051.719
Msc : 합성후 고정하중에 의한 모멘트	kN · m	-4970.766
Mv : (활하중 + 지점침하)에 의한 모멘트	kN · m	-10292.323
Ss : 합성전 고정하중에 의한 전단력	kN	-1917.673
Ssc : 합성후 고정하중에 의한 전단력	kN	-521.651
Sv : (활하중 + 지점침하)에 의한 전단력	kN	-1067.349
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-0.176
Mscst : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-28.926
Mvt : (활하중 + 지점침하)에 의한 비틀림모멘트	kN · m	-795.585
t _{cu} , t _{cl} : 교축방향 철근의 피복두께	mm	50 , 50

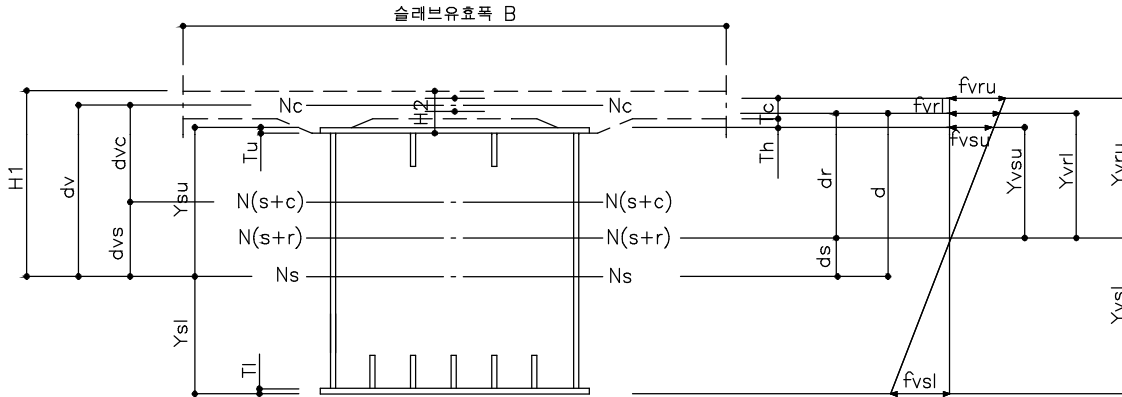
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

단 면 제 원

단 면	B(mm)	H(mm)	A(mm ²)	Y(mm)	A*Y(mm ³)	A*Y2(mm ⁴)	Ix(mm ⁴)
1 - UPPER FLANGE	2432.0	28.0	68096	1314.00	89478144	117574281216	4448939
3 - UPPER RIB	14.0	150.0	6300	1225.00	7717500	9453937500	11812500
1 - L_WEB	12.0	2600.0	31200	0.00	0	0	17576000000
1 - R_WEB	12.0	2600.0	31200	0.00	0	0	17576000000
5 - LOWER RIB	14.0	150.0	10500	-1225.00	-12862500	15756562500	19687500
1 - LOWER FLANGE	2432.0	28.0	68096	-1314.00	-89478144	117574281216	4448939
강단면 합계			215392		-5145000	260359062432	35192397877
UPPER RE-BAR	-	-	3773.40	1550.00	5848770	9065593500	-
LOWER RE-BAR	-	-	6752.40	1400.00	9453360	13234704000	-
RE-BAR 합계			10526		15302130	22300297500	-
1 - RC SLAB	5145.0	250.0	1286250	1475.00	1897218750	2798397656250	6699218750

$$* A_s = 215392 \text{ mm}^2, A_c = 1286250 \text{ mm}^2, A_r = 10526 \text{ mm}^2$$

2) 응력 검토



(1) 합 성 전

$$|s'| = A_s \cdot Y_2 + \sum |s| = 260359062432 + 35192397877 = 295551460309 \text{ mm}^4$$

$$\delta s = \sum(A \cdot Y) / A_s = -5145000 / 215392 = -23.887 \text{ mm}$$

$$I_s = I_{s'} - A_s \cdot \delta s^2 = 29551460309 - 215392 \times -23.887^2 = 295428563335 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta_s = 2600.0 / 2 + 28.0 - -23.887 = 1351.887 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1351.887 - 2656.000 = -1304.113 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + TI/2) = 6601536.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = -82.605 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = 79.686 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot T_w) = 30.733 \text{ MPa}$$

(2) 합 성 후

$$\begin{aligned}A_v &= A_s + A_r = 225918 \text{ mm}^2 \\d &= Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1477.660 \text{ mm} \\d_r &= d \cdot A_s / (A_s + A_r) = 1408.814 \text{ mm} \\d_s &= d - d_r = 68.846 \text{ mm} \\Y_{vru} &= d_r + (T_c - t_{cu} - t_{cl}) \cdot A_{rl}/A_r = 1505.041 \text{ mm} \\Y_{vrl} &= d_r - (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1355.041 \text{ mm} \\Y_{vsu} &= Y_{vrl} - t_{cl} - T_h + T_u = 1283.041 \text{ mm} \\Y_{vsl} &= Y_{vsu} - (H + T_u + T_l) = -1372.959 \text{ mm} \\I_{rv} &= I_s + A_s \cdot d_s^2 + A_r \cdot d_r^2 = 317340634169 \text{ mm}^4 \\F_v &= b \cdot h_v = ((UL2 + UR2 + B2) / 2 + T_w) \cdot (H + (T_u + T_c/n)/2 + T_l/2) = 6640786.0 \text{ mm}^2 \\f_{vru} &= M_{sc} \cdot Y_{vru}/I_{rv} = -23.575 \text{ MPa} \\f_{vrl} &= M_{sc} \cdot Y_{vrl}/I_{rv} = -21.225 \text{ MPa} \\f_{vsu} &= M_{sc} \cdot Y_{vsu}/I_{rv} = -20.097 \text{ MPa} \\f_{vsl} &= M_{sc} \cdot Y_{vsl}/I_{rv} = 21.506 \text{ MPa} \\u &= S_{sc} / A(\text{Web}) + M_{sct} / (2 \cdot F_v \cdot T_w) = 8.541 \text{ MPa}\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}f_{vru} &= M_v \cdot Y_{vru}/I_{rv} = -48.813 \text{ MPa} \\f_{vrl} &= M_v \cdot Y_{vrl}/I_{rv} = -43.948 \text{ MPa} \\f_{vsu} &= M_v \cdot Y_{vsu}/I_{rv} = -41.613 \text{ MPa} \\f_{vsl} &= M_v \cdot Y_{vsl}/I_{rv} = 44.529 \text{ MPa} \\u &= S_v / A(\text{Web}) + M_{vt} / (2 \cdot F_v \cdot T_w) = 22.097 \text{ MPa}\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}A_{vc} &= A_s + A_c/n = 376173.250 \text{ mm}^2 \\d_v &= Y_{su} - T_u + T_h + T_c/2 = 1498.887 \text{ mm} \\d_{vc} &= d_v \cdot A_s / (A_c/n + A_s) = 858.243 \text{ mm} \\d_{vs} &= d_v - d_{vc} = 640.643 \text{ mm} \\n_1 &= n \cdot (1 + \phi_1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\A_{v1} &= A_s + A_c/n_1 = 295782.625 \text{ mm}^2 \quad \# \text{ 2차 부정정력으로 인한 영향 고려} \\d_{c1} &= d_v \cdot A_s / (A_c/n_1 + A_s) = 1091.505 \text{ mm} \quad K = -0.197 \\d_{s1} &= d_v - d_{c1} = 407.382 \text{ mm} \\I_{cv} &= I_s + I_c/n + A_s \cdot d_{vs}^2 + A_c/n \cdot d_{vc}^2 = 503096503584.7 \text{ mm}^4 \\N_c &= M_{sc} \cdot d_{vc} \cdot A_c / (n \cdot I_{cv}) = -1363383 \text{ N} \\P\phi &= N_c \cdot 2 \cdot \phi_1 / (2 + \phi_1) = -1363383 \text{ N} \\M\phi &= P\phi \cdot d_{c1} = -1488139319 \text{ N} \cdot \text{mm} \\E_{c1} &= E_c / (1 + \phi_1 / 2) = 13351 \text{ MPa} \\f_{vru1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vru}/I_{rv} = -4.644 \text{ MPa} \\f_{vrl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vrl}/I_{rv} = -4.783 \text{ MPa} \\f_{vsu1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsu} / I_{rv} = -4.850 \text{ MPa} \\f_{vsl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsl} / I_{rv} = -7.303 \text{ MPa}\end{aligned}$$

(5) 건조수축

$$n_2 = n \cdot (1 + \phi_2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$A_{v2} = A_s + A_c/n_2 = 268985.750 \text{ mm}^2$$

$$d_{c2} = d_v \cdot A_s / (A_c/n_2 + A_s) = 1200.243 \text{ mm}$$

$$d_{s2} = d_v - d_{c2} = 298.644 \text{ mm}$$

$$P_2 = E_s \cdot \epsilon_s \cdot A_c/n_2 = 2025844 \text{ N}$$

$$M_{v2} = P_2 \cdot d_{c2} = 2431504302 \text{ N} \cdot \text{mm}$$

$$f_{vru2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vru}/I_{rv} = 6.695 \text{ MPa}$$

$$f_{vrl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vrl}/I_{rv} = 6.922 \text{ MPa}$$

$$f_{vsu2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsu}/I_{rv} = 7.031 \text{ MPa}$$

$$f_{vsl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsl}/I_{rv} = 11.040 \text{ MPa}$$

(6) 온도차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P_1 = E_s \cdot \epsilon_t \cdot A_c/n = 4051688 \text{ N}$$

$$M_{vt} = P_1 \cdot d_{vc} = 3477333958 \text{ N} \cdot \text{mm}$$

$$E_{rt} = E_s \cdot \epsilon_t = 25.200 \text{ MPa}$$

$$f_{rut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vru}/I_{rv} - E_s \cdot \epsilon_t = -10.515 \text{ MPa}$$

$$f_{rlt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vrl}/I_{rv} - E_s \cdot \epsilon_t = -10.191 \text{ MPa}$$

$$f_{sut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsu}/I_{rv} = 15.165 \text{ MPa}$$

$$f_{slt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsl}/I_{rv} = 20.898 \text{ MPa}$$

(7) 전단 및 비틀림

$$u = (S_s + S_{sc} + S_v)/A_w + (M_{st}/(2 F T_w) + (M_{sct} + M_{vt})/(2 F_v T_w)) = 61.371 \text{ MPa} < u_a = 110 \text{ MPa} \quad 0.K!!!$$

(8) 조합응력의 검토 (도.설 3.4.2.1)

$$i = 0.65(\phi/n)^2 + 0.13(\phi/n) + 1.0$$

$$= 0.650 \times (0.0 / 6)^2 + 0.130 \times (0.0 / 6) + 1.0 = 1.000$$

$$\therefore \phi = (f_1 - f_2)/f_1 \approx 0$$

여기서, n : 종리브에 의해서 구분되는 Pannel의 수

i : 응력구배계수 ϕ : 응력구배

f_1, f_2 : 보강된 판의 양면의 응력

(단, $f_1 \geq f_2$ 이며 압축응력을 정(+)으로 한다.)

* 인장 (상부)플랜지의 허용응력 (SM490 사용)

$$f_{ta} = 190.0 \text{ MPa}$$

* 압축 (하부)플랜지의 허용응력 (SM490 사용)

$$t_l \geq \frac{b}{24 \cdot i \cdot n} = \frac{2500}{24 \times 1.000 \times 6} = 17.361 \text{ mm}$$

인 경우 : $f_{ca} = 190.0 \text{ MPa}$

$$\frac{b}{24 \cdot i \cdot n} > t_l \geq \frac{b}{49 \cdot i \cdot n} = \frac{2500}{49 \times 1.000 \times 6} = 8.503 \text{ mm}$$

인 경우 : $f_{ca} = 190 - 3.9 (b / (t_l \cdot i \cdot n) - 24) = 225.564$

$$\frac{b}{49 \cdot i \cdot n} > t_l \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.208 \text{ mm}$$

인 경우 : $f_{ca} = 220000 \times \{ (t_l \cdot i \cdot n) / b \} = 993.485 \text{ MPa}$

사용 $t_l = 28.0 \text{ mm}$

따라서, $f_{ca} = 190.000 \text{ MPa}$

* RE-BAR의 허용응력 (도.설 2.2.2.4, 3.6.1.7)

$f_{ta} = 160.000 \text{ MPa}$ $f_{ca} = 180.000 \text{ MPa}$ (SD400 사용)

하중조합	RE-BAR			STEEL			
	작용응력 (MPa)		허용응력	작용응력 (MPa)		허용응력 (MPa)	
	상 연	하 연	(MPa)	상 연	하 연	상 연	하 연
1			160.000	-82.605	79.686	190.000	190.000
1+2+3	-72.388	-65.173	160.000	-144.315	145.721	190.000	190.000
1+2+3+4	-77.032	-69.956	160.000	-149.165	138.418	190.000	190.000
1+2+3+4+5	-70.337	-63.034	160.000	-142.134	149.457	190.000	190.000
1+2+3+4+5+6	-80.851	-73.225	184.000	-126.970	170.355	218.500	218.500
1+2+3+4+5-6	-59.822	-52.844	184.000	-157.299	128.559	218.500	218.500

주) 압축응력을 정(+), 인장응력을 부(-)로 하였음.

허용응력의 할증 (도.설 3.9.3.1 참조)

(9) 합성응력의 검토 (도.설 3.8.2.4)

(상 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{-149.165}{190.000} \right)^2 + \left(\frac{61.371}{110.000} \right)^2 \\ &= 0.616 + 0.311 = 0.928 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(하 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{149.457}{190.000} \right)^2 + \left(\frac{61.371}{110.000} \right)^2 \\ &= 0.619 + 0.311 = 0.930 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(10) 판의 최소두께 검토

인장(상부)플랜지 (도.설.기 3.8.3.1)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = 10 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K.} \quad (\text{합성형 스테드 설치})$$

압축(하부)플랜지 (도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

복부판 수평보강재 사용단수 1 단 (도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 9.9 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 79.686)} = 1.544 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = b / (219 \times 1.056) = 11.2 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 170.355)} = 1.056 < 1.2 \Rightarrow 1.056$$

(11) 항복에 대한 안전도 검사 (도.설.해(2003) 3.9.3.2)

$\Sigma f = 1.3 \times (\text{합성전 사하중 응력} + \text{합성후 사하중}) + 2.15 \times \text{활하중에 의한 응력(충격포함)}$
 $+ (\text{크리프응력 변화량}) + (\text{건조수축응력변화량}) + (\text{온도차응력변화량})$ 의 조합 중에서
 가장 불리한 하중 조합에 대하여 검토

① 상부바닥판 REBAR

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vru} = -23.575 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -72.388 - -23.575 = -48.813 \text{ MPa}$$

$$\Sigma f = 1.3 \times -23.575 + 2.15 \times -48.813 + (-4.644) + (6.695) + (-10.515) \\ = -144.059 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times -23.575 + 2.15 \times -48.813 + (-10.515) \\ = -146.110 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = -82.605 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsu} = -20.097 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -144.315 - -82.605 - -20.097 = -41.613 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-82.605 + -20.097) + 2.15 \times -41.613 + (-4.85) + (7.031) + (-15.165) \\ = -235.965 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (-82.605 + -20.097) + 2.15 \times -41.613 + (-15.165) \\ = -238.145 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = 79.686 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsl} = 21.506 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 145.721 - 79.686 - 21.506 = 44.529 \text{ MPa}$$

$$\Sigma f = 1.3 \times (79.686 + 21.506) + 2.15 \times 44.529 + (-7.303) + (11.04) + (20.898) \\ = 251.921 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

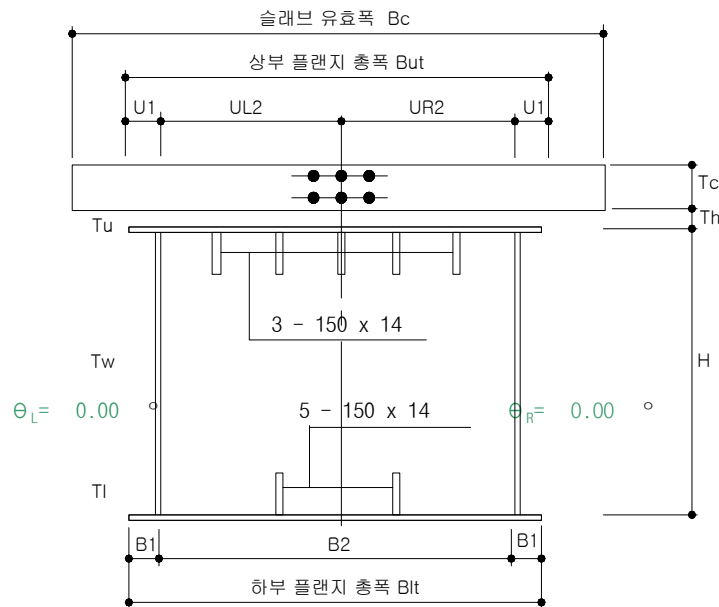
$$\Sigma f = 1.3 \times (79.686 + 21.506) + 2.15 \times 44.529 + (20.898) \\ = 248.185 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	-144.059	400.000	0.K!!!	2.77
	크리프, 건조수축제외시	-146.110	400.000	0.K!!!	2.73
상부플랜지	크리프, 건조수축 포함시	-235.965	315.000	0.K!!!	1.33
	크리프, 건조수축제외시	-238.145	315.000	0.K!!!	1.32
하부플랜지	크리프, 건조수축 포함시	251.921	315.000	0.K!!!	1.25
	크리프, 건조수축제외시	248.185	315.000	0.K!!!	1.26

5-8. 2경간 최대 부모멘트 단면검토(G1)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.600 m

Bc = 5.145 m

UL2= 1.250 , UR2= 1.250 m

B2 = 2.500 m

But= 2.700 , Bit= 2.700 m

상하 플랜지 유효폭

Bue= 2.432 , Ble= 2.432 m

Tc = 0.250 m

Th = 0.050 m

Tu = 0.028 m

Tl = 0.028 m

Tw = 0.012 m

U1 = 0.100 m

B1 = 0.100 m

RIB 150 x 14 mm , 150 x 14 mm

구 분	단 위	입력 DATA
Es : 강의 탄성계수	MPa	210000
Ec : 콘크리트의 탄성계수	MPa	26702
εs: 바닥판 콘크리트의 건조수축에 의한 최종수축율		0.00018
α : 강재 및 콘크리트의 선팅창계수		0.000012
φ2: 건조수축에 의한 크리이프계수		4
n : 강과 콘크리트의 탄성계수비		8
t : 강과 콘크리트의 온도차	℃	10
Ms : 합성전 고정하중에 의한 모멘트	kN · m	-18051.719
Msc : 합성후 고정하중에 의한 모멘트	kN · m	-4970.766
Mv : (활하중 + 지점침하)에 의한 모멘트	kN · m	-10292.323
Ss : 합성전 고정하중에 의한 전단력	kN	-1581.203
Ssc : 합성후 고정하중에 의한 전단력	kN	-438.662
Sv : (활하중 + 지점침하)에 의한 전단력	kN	-1016.853
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-0.357
Mscst : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-7.822
Mvt : (활하중 + 지점침하)에 의한 비틀림모멘트	kN · m	-753.240
tcu,tcl : 교축방향 철근의 피복두께	mm	50 , 50

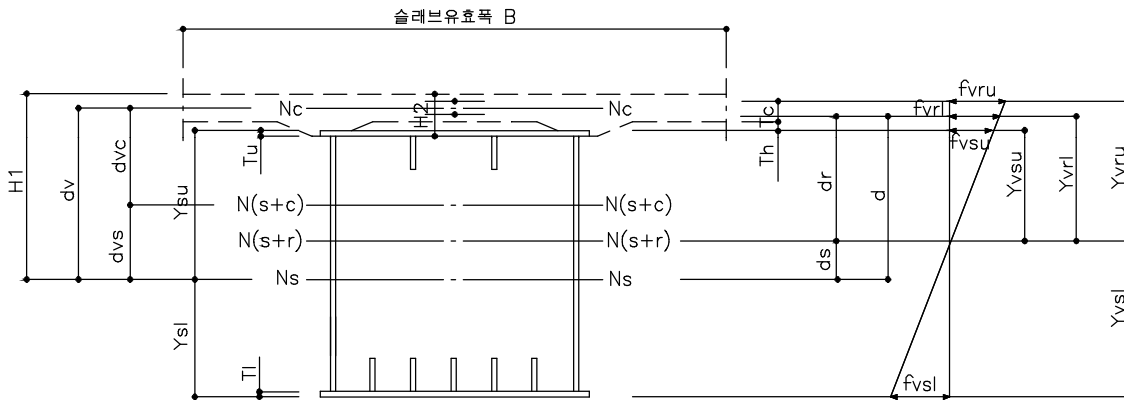
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

단 면 제 원

단 면	B(mm)	H(mm)	A(mm ²)	Y(mm)	A*Y(mm ³)	A*Y2(mm ⁴)	Ix(mm ⁴)
1 - UPPER FLANGE	2432.0	28.0	68096	1314.00	89478144	117574281216	4448939
3 - UPPER RIB	14.0	150.0	6300	1225.00	7717500	9453937500	11812500
1 - L_WEB	12.0	2600.0	31200	0.00	0	0	17576000000
1 - R_WEB	12.0	2600.0	31200	0.00	0	0	17576000000
5 - LOWER RIB	14.0	150.0	10500	-1225.00	-12862500	15756562500	19687500
1 - LOWER FLANGE	2432.0	28.0	68096	-1314.00	-89478144	117574281216	4448939
강단면 합계			215392		-5145000	260359062432	35192397877
UPPER RE-BAR	-	-	3773.40	1550.00	5848770	9065593500	-
LOWER RE-BAR	-	-	6752.40	1400.00	9453360	13234704000	-
RE-BAR 합계			10526		15302130	22300297500	-
1 - RC SLAB	5145.0	250.0	1286250	1475.00	1897218750	2798397656250	6699218750

* $A_s = 215392 \text{ mm}^2$, $A_c = 1286250 \text{ mm}^2$, $A_r = 10526 \text{ mm}^2$

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = 260359062432 + 35192397877 = 295551460309 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -5145000 / 215392 = -23.887 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = 295551460309 - 215392 \times (-23.887)^2 = 295428563335 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2600.0 / 2 + 28.0 - (-23.887) = 1351.887 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1351.887 - 2656.000 = -1304.113 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6601536.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = -82.605 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = 79.686 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 25.342 \text{ MPa}$$

(2) 합 성 후

$$\begin{aligned}A_v &= A_s + A_r = 225918 \text{ mm}^2 \\d &= Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1477.660 \text{ mm} \\d_r &= d \cdot A_s / (A_s + A_r) = 1408.814 \text{ mm} \\d_s &= d - d_r = 68.846 \text{ mm} \\Y_{vru} &= d_r + (T_c - t_{cu} - t_{cl}) \cdot A_{rl}/A_r = 1505.041 \text{ mm} \\Y_{vrl} &= d_r - (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1355.041 \text{ mm} \\Y_{vsu} &= Y_{vrl} - t_{cl} - T_h + T_u = 1283.041 \text{ mm} \\Y_{vsl} &= Y_{vsu} - (H + T_u + T_l) = -1372.959 \text{ mm} \\I_{rv} &= I_s + A_s \cdot d_s^2 + A_r \cdot d_r^2 = 317340634169 \text{ mm}^4 \\F_v &= b \cdot h_v = ((U_L2 + U_R2 + B2) / 2 + T_w) \cdot (H + (T_u + T_c/n)/2 + T_l/2) = 6640786.0 \text{ mm}^2 \\f_{vru} &= M_{sc} \cdot Y_{vru}/I_{rv} = -23.575 \text{ MPa} \\f_{vrl} &= M_{sc} \cdot Y_{vrl}/I_{rv} = -21.225 \text{ MPa} \\f_{vsu} &= M_{sc} \cdot Y_{vsu}/I_{rv} = -20.097 \text{ MPa} \\f_{vsl} &= M_{sc} \cdot Y_{vsl}/I_{rv} = 21.506 \text{ MPa} \\u &= S_{sc} / A(\text{Web}) + M_{sct} / (2 \cdot F_v \cdot T_w) = 7.079 \text{ MPa}\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}f_{vru} &= M_v \cdot Y_{vru}/I_{rv} = -48.813 \text{ MPa} \\f_{vrl} &= M_v \cdot Y_{vrl}/I_{rv} = -43.948 \text{ MPa} \\f_{vsu} &= M_v \cdot Y_{vsu}/I_{rv} = -41.613 \text{ MPa} \\f_{vsl} &= M_v \cdot Y_{vsl}/I_{rv} = 44.529 \text{ MPa} \\u &= S_v / A(\text{Web}) + M_{vt} / (2 \cdot F_v \cdot T_w) = 21.022 \text{ MPa}\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}A_{vc} &= A_s + A_c/n = 376173.250 \text{ mm}^2 \\d_v &= Y_{su} - T_u + T_h + T_c/2 = 1498.887 \text{ mm} \\d_{vc} &= d_v \cdot A_s / (A_c/n + A_s) = 858.243 \text{ mm} \\d_{vs} &= d_v - d_{vc} = 640.643 \text{ mm} \\n_1 &= n \cdot (1 + \phi_1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\A_{v1} &= A_s + A_c/n_1 = 295782.625 \text{ mm}^2 \quad \# \text{ 2차 부정정력으로 인한 영향 고려} \\d_{c1} &= d_v \cdot A_s / (A_c/n_1 + A_s) = 1091.505 \text{ mm} \quad K = -0.197 \\d_{s1} &= d_v - d_{c1} = 407.382 \text{ mm} \\I_{cv} &= I_s + I_c/n + A_s \cdot d_{vs}^2 + A_c/n \cdot d_{vc}^2 = 503096503584.7 \text{ mm}^4 \\N_c &= M_{sc} \cdot d_{vc} \cdot A_c/(n \cdot I_{cv}) = -1363383 \text{ N} \\P\phi &= N_c \cdot 2 \cdot \phi_1 / (2 + \phi_1) = -1363383 \text{ N} \\M\phi &= P\phi \cdot d_{c1} = -1488139319 \text{ N} \cdot \text{mm} \\E_{c1} &= E_c / (1 + \phi_1 / 2) = 13351 \text{ MPa} \\f_{vru1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vru}/I_{rv} = -4.644 \text{ MPa} \\f_{vrl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vrl}/I_{rv} = -4.783 \text{ MPa} \\f_{vsu1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsu} / I_{rv} = -4.850 \text{ MPa} \\f_{vsl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsl} / I_{rv} = -7.303 \text{ MPa}\end{aligned}$$

(5) 건조수축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 268985.750 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1200.243 \text{ mm}$$

$$ds2 = dv - dc2 = 298.644 \text{ mm}$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 2025844 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2431504302 \text{ N} \cdot \text{mm}$$

$$fvru2 = P2/Av + K \cdot Mv2 \cdot Yvru/lrv = 6.695 \text{ MPa}$$

$$fvrl2 = P2/Av + K \cdot Mv2 \cdot Yvrl/lrv = 6.922 \text{ MPa}$$

$$fvru2 = P2/Av + K \cdot Mv2 \cdot Yvsu/lrv = 7.031 \text{ MPa}$$

$$fvsl2 = P2/Av + K \cdot Mv2 \cdot Yvsl/lrv = 11.040 \text{ MPa}$$

(6) 온도차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 4051688 \text{ N}$$

$$Mvt = P1 \cdot dvc = 3477333958 \text{ N} \cdot \text{mm}$$

$$Ert = Es \cdot \epsilon_t = 25.200 \text{ MPa}$$

$$frut = P1/Av + K \cdot Mvt \cdot Yvru/lrv - Es \cdot \epsilon_t = -10.515 \text{ MPa}$$

$$frlt = P1/Av + K \cdot Mvt \cdot Yvrl/lrv - Es \cdot \epsilon_t = -10.191 \text{ MPa}$$

$$fsut = P1/Av + K \cdot Mvt \cdot Yvsu/lrv = 15.165 \text{ MPa}$$

$$fslt = P1/Av + K \cdot Mvt \cdot Yvsl/lrv = 20.898 \text{ MPa}$$

(7) 전단 및 비틀림

$$u = (Ss+Ssc+Sv)/Aw + (Mst/(2 F Tw)+(Msct+Mvt)/(2 Fv Tw)) = 53.443 \text{ MPa} < u_a = 110 \text{ MPa} \quad 0.K!!!$$

(8) 조합응력의 검토 (도.설 3.4.2.1)

$$i = 0.65(\phi/n)^2 + 0.13(\phi/n) + 1.0$$

$$= 0.650 \times (0.0 / 6)^2 + 0.130 \times (0.0 / 6) + 1.0 = 1.000$$

$$\therefore \phi = (f_1 - f_2) / f_1 \approx 0$$

여기서, n : 종리브에 의해서 구분되는 Pannel의 수

i : 응력구배계수 ϕ : 응력구배

f_1, f_2 : 보강된 판의 양면의 응력

(단, $f_1 \geq f_2$ 이며 압축응력을 정(+)으로 한다.)

* 인장 (상부)플랜지의 허용응력 (SM490 사용)

$$fta = 190.0 \text{ MPa}$$

* 압축 (하부)플랜지의 허용응력 (SM490 사용)

$$t_l \geq \frac{b}{24 \cdot i \cdot n} = \frac{2500}{24 \times 1.000 \times 6} = 17.361 \text{ mm}$$

인 경우 : $f_{ca} = 190.0 \text{ MPa}$

$$\frac{b}{24 \cdot i \cdot n} > t_l \geq \frac{b}{49 \cdot i \cdot n} = \frac{2500}{49 \times 1.000 \times 6} = 8.503 \text{ mm}$$

인 경우 : $f_{ca} = 190 - 3.9 (b / (t_l \cdot i \cdot n) - 24) = 225.564$

$$\frac{b}{49 \cdot i \cdot n} > t_l \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.208 \text{ mm}$$

인 경우 : $f_{ca} = 220000 \times \{ (t_l \cdot i \cdot n) / b \} = 993.485 \text{ MPa}$

사용 $t_l = 28.0 \text{ mm}$

따라서, $f_{ca} = 190.000 \text{ MPa}$

* RE-BAR의 허용응력 (도.설 2.2.2.4, 3.6.1.7)

$f_{ta} = 160.000 \text{ MPa}$ $f_{ca} = 180.000 \text{ MPa}$ (SD400 사용)

하중조합	RE-BAR			STEEL			
	작용응력 (MPa)		허용응력	작용응력 (MPa)		허용응력 (MPa)	
	상 연	하 연	(MPa)	상 연	하 연	상 연	하 연
1			160.000	-82.605	79.686	190.000	190.000
1+2+3	-72.388	-65.173	160.000	-144.315	145.721	190.000	190.000
1+2+3+4	-77.032	-69.956	160.000	-149.165	138.418	190.000	190.000
1+2+3+4+5	-70.337	-63.034	160.000	-142.134	149.457	190.000	190.000
1+2+3+4+5+6	-80.851	-73.225	184.000	-126.970	170.355	218.500	218.500
1+2+3+4+5-6	-59.822	-52.844	184.000	-157.299	128.559	218.500	218.500

주) 압축응력을 정(+), 인장응력을 부(-)로 하였음.

허용응력의 할증 (도.설 3.9.3.1 참조)

(9) 합성응력의 검토 (도.설 3.8.2.4)

(상 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{-149.165}{190.000} \right)^2 + \left(\frac{53.443}{110.000} \right)^2 \\ &= 0.616 + 0.236 = 0.852 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(하 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{149.457}{190.000} \right)^2 + \left(\frac{53.443}{110.000} \right)^2 \\ &= 0.619 + 0.236 = 0.855 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(10) 판의 최소두께 검토

인장(상부)플랜지 (도.설.기 3.8.3.1)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = 10 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K.} \quad (\text{합성형 스테드 설치})$$

압축(하부)플랜지 (도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

복부판 수평보강재 사용단수 1 단 (도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 9.9 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 79.686)} = 1.544 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = b / (219 \times 1.056) = 11.2 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 170.355)} = 1.056 < 1.2 \Rightarrow 1.056$$

(11) 항복에 대한 안전도 검사 (도.설.해(2003) 3.9.3.2)

$\Sigma f = 1.3 \times (\text{합성전 사하중 응력} + \text{합성후 사하중}) + 2.15 \times \text{활하중에 의한 응력(충격포함)}$
 $+ (\text{크리프응력 변화량}) + (\text{건조수축응력변화량}) + (\text{온도차응력변화량})$ 의 조합 중에서
 가장 불리한 하중 조합에 대하여 검토

① 상부바닥판 REBAR

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vru} = -23.575 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -72.388 - -23.575 = -48.813 \text{ MPa}$$

$$\Sigma f = 1.3 \times -23.575 + 2.15 \times -48.813 + (-4.644) + (6.695) + (-10.515) \\ = -144.059 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times -23.575 + 2.15 \times -48.813 + (-10.515) \\ = -146.110 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = -82.605 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsu} = -20.097 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -144.315 - -82.605 - -20.097 = -41.613 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-82.605 + -20.097) + 2.15 \times -41.613 + (-4.85) + (7.031) + (-15.165) \\ = -235.965 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (-82.605 + -20.097) + 2.15 \times -41.613 + (-15.165) \\ = -238.145 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = 79.686 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsl} = 21.506 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 145.721 - 79.686 - 21.506 = 44.529 \text{ MPa}$$

$$\Sigma f = 1.3 \times (79.686 + 21.506) + 2.15 \times 44.529 + (-7.303) + (11.04) + (20.898) \\ = 251.921 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

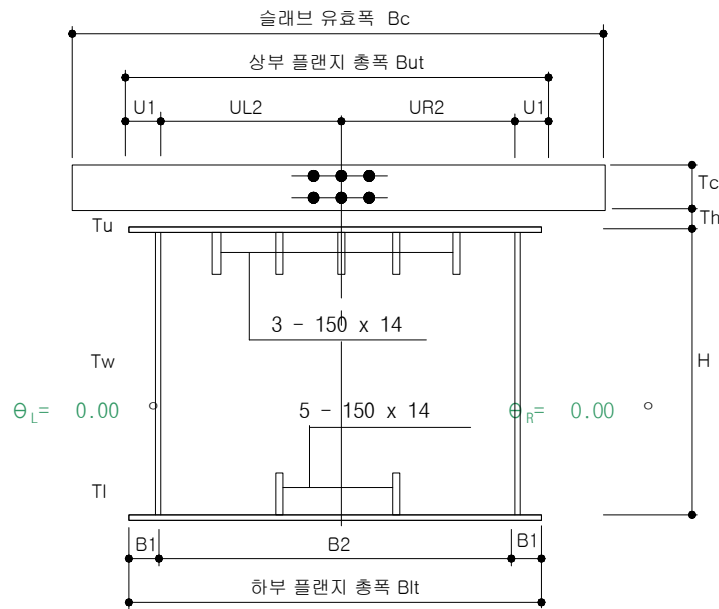
$$\Sigma f = 1.3 \times (79.686 + 21.506) + 2.15 \times 44.529 + (20.898) \\ = 248.185 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	-144.059	400.000	0.K!!!	2.77
	크리프, 건조수축제외시	-146.110	400.000	0.K!!!	2.73
상부플랜지	크리프, 건조수축 포함시	-235.965	315.000	0.K!!!	1.33
	크리프, 건조수축제외시	-238.145	315.000	0.K!!!	1.32
하부플랜지	크리프, 건조수축 포함시	251.921	315.000	0.K!!!	1.25
	크리프, 건조수축제외시	248.185	315.000	0.K!!!	1.26

5-9. 1경간 최대 부모멘트 단면검토(G2)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.600 m

Bc = 5.153 m

UL2= 1.250 , UR2= 1.250 m

B2 = 2.500 m

But= 2.700 , Blt= 2.700 m

상하 플랜지 유효폭

Bue= 2.432 , Ble= 2.432 m

Tc = 0.250 m

Th = 0.050 m

Tu = 0.028 m

TI = 0.028 m

Tw = 0.012 m

U1 = 0.100 m

B1 = 0.100 m

RIB 150 x 14 mm , 150 x 14 mm

구 분	단 위	입력 DATA
Es : 강역 탄성계수	MPa	210000
Ec : 콘크리트의 탄성계수	MPa	26702
εs: 바닥판 콘크리트의 건조수축에 의한 최종수축율		0.00018
α : 강재 및 콘크리트의 선팅창계수		0.000012
φ2: 건조수축에 의한 크리이프계수		4
n : 강과 콘크리트의 탄성계수비		8
t : 강과 콘크리트의 온도차	℃	10
Ms : 합성전 고정하중에 의한 모멘트	kN · m	-18051.719
Msc : 합성후 고정하중에 의한 모멘트	kN · m	-4970.766
Mv : (활하중 + 지점침하)에 의한 모멘트	kN · m	-10292.323
Ss : 합성전 고정하중에 의한 전단력	kN	-1919.624
Ssc : 합성후 고정하중에 의한 전단력	kN	-459.913
Sv : (활하중 + 지점침하)에 의한 전단력	kN	-904.073
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-0.023
Mscst : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-27.108
Mvt : (활하중 + 지점침하)에 의한 비틀림모멘트	kN · m	-935.562
t _{cu} , t _{cl} : 교축방향 철근의 피복두께	mm	50 , 50

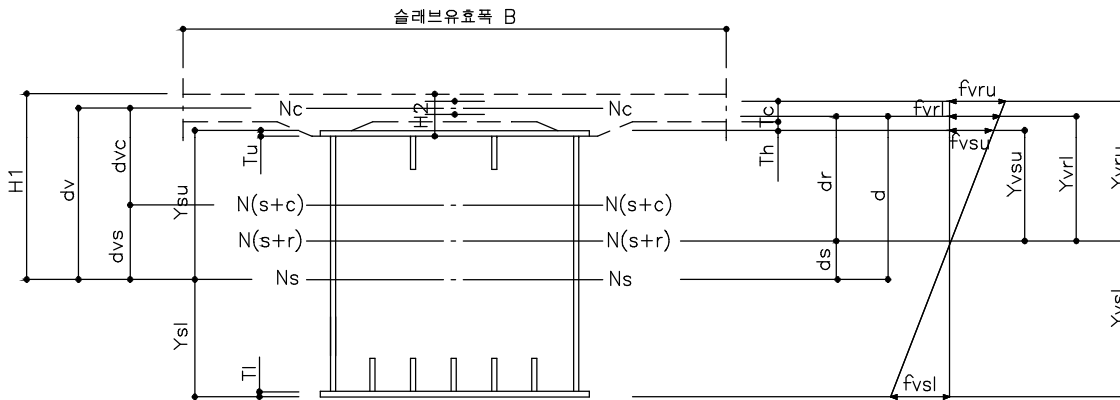
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

단 면 제 원

단 면	B(mm)	H(mm)	A(mm ²)	Y(mm)	A*Y(mm ³)	A*Y2(mm ⁴)	Ix(mm ⁴)
1 - UPPER FLANGE	2432.0	28.0	68096	1314.00	89478144	117574281216	4448939
3 - UPPER RIB	14.0	150.0	6300	1225.00	7717500	9453937500	11812500
1 - L_WEB	12.0	2600.0	31200	0.00	0	0	17576000000
1 - R_WEB	12.0	2600.0	31200	0.00	0	0	17576000000
5 - LOWER RIB	14.0	150.0	10500	-1225.00	-12862500	15756562500	19687500
1 - LOWER FLANGE	2432.0	28.0	68096	-1314.00	-89478144	117574281216	4448939
강단면 합계			215392		-5145000	260359062432	35192397877
UPPER RE-BAR	-	-	4269.90	1550.00	6618345	10258434750	-
LOWER RE-BAR	-	-	6255.90	1400.00	8758260	12261564000	-
RE-BAR 합계			10526		15376605	22519998750	-
1 - RC SLAB	5153.0	250.0	1288250	1475.00	1900168750	2802748906250	6709635417

* $A_s = 215392 \text{ mm}^2$, $A_c = 1288250 \text{ mm}^2$, $A_r = 10526 \text{ mm}^2$

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = 260359062432 + 35192397877 = 295551460309 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -5145000 / 215392 = -23.887 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = 295551460309 - 215392 \times (-23.887)^2 = 295428563335 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2600.0 / 2 + 28.0 - (-23.887) = 1351.887 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1351.887 - 2656.000 = -1304.113 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + T_u/2 + T_l/2) = 6601536.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = -82.605 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = 79.686 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 30.763 \text{ MPa}$$

(2) 합 성 후

$$\begin{aligned}A_v &= A_s + A_r = 225918 \text{ mm}^2 \\d &= Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1484.736 \text{ mm} \\d_r &= d \cdot A_s / (A_s + A_r) = 1415.560 \text{ mm} \\d_s &= d - d_r = 69.176 \text{ mm} \\Y_{vru} &= d_r + (T_c - t_{cu} - t_{cl}) \cdot A_{rl}/A_r = 1504.711 \text{ mm} \\Y_{vrl} &= d_r - (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1354.711 \text{ mm} \\Y_{vsu} &= Y_{vrl} - t_{cl} - T_h + T_u = 1282.711 \text{ mm} \\Y_{vsl} &= Y_{vsu} - (H + T_u + T_l) = -1373.289 \text{ mm} \\I_{rv} &= I_s + A_s \cdot d_s^2 + A_r \cdot d_r^2 = 317550979436 \text{ mm}^4 \\F_v &= b \cdot h_v = ((UL2 + UR2 + B2) / 2 + T_w) \cdot (H + (T_u + T_c/n)/2 + T_l/2) = 6640786.0 \text{ mm}^2 \\f_{vru} &= M_{sc} \cdot Y_{vru}/I_{rv} = -23.554 \text{ MPa} \\f_{vrl} &= M_{sc} \cdot Y_{vrl}/I_{rv} = -21.206 \text{ MPa} \\f_{vsu} &= M_{sc} \cdot Y_{vsu}/I_{rv} = -20.079 \text{ MPa} \\f_{vsl} &= M_{sc} \cdot Y_{vsl}/I_{rv} = 21.497 \text{ MPa} \\u &= S_{sc} / A(\text{Web}) + M_{sct} / (2 \cdot F_v \cdot T_w) = 7.540 \text{ MPa}\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}f_{vru} &= M_v \cdot Y_{vru}/I_{rv} = -48.770 \text{ MPa} \\f_{vrl} &= M_v \cdot Y_{vrl}/I_{rv} = -43.908 \text{ MPa} \\f_{vsu} &= M_v \cdot Y_{vsu}/I_{rv} = -41.575 \text{ MPa} \\f_{vsl} &= M_v \cdot Y_{vsl}/I_{rv} = 44.510 \text{ MPa} \\u &= S_v / A(\text{Web}) + M_{vt} / (2 \cdot F_v \cdot T_w) = 20.358 \text{ MPa}\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}A_{vc} &= A_s + A_c/n = 376423.250 \text{ mm}^2 \\d_v &= Y_{su} - T_u + T_h + T_c/2 = 1498.887 \text{ mm} \\d_{vc} &= d_v \cdot A_s / (A_c/n + A_s) = 857.673 \text{ mm} \\d_{vs} &= d_v - d_{vc} = 641.213 \text{ mm} \\n_1 &= n \cdot (1 + \phi_1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\A_{v1} &= A_s + A_c/n_1 = 295907.625 \text{ mm}^2 \quad \# \text{ 2차 부정정력으로 인한 영향 고려} \\d_{c1} &= d_v \cdot A_s / (A_c/n_1 + A_s) = 1091.044 \text{ mm} \quad K = -0.197 \\d_{s1} &= d_v - d_{c1} = 407.843 \text{ mm} \\I_{cv} &= I_s + I_c/n + A_s \cdot d_{vs}^2 + A_c/n \cdot d_{vc}^2 = 503281828791.6 \text{ mm}^4 \\N_c &= M_{sc} \cdot d_{vc} \cdot A_c/(n \cdot I_{cv}) = -1364094 \text{ N} \\P\phi &= N_c \cdot 2 \cdot \phi_1 / (2 + \phi_1) = -1364094 \text{ N} \\M\phi &= P\phi \cdot d_{c1} = -1488285928 \text{ N} \cdot \text{mm} \\E_{c1} &= E_c / (1 + \phi_1 / 2) = 13351 \text{ MPa} \\f_{vru1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vru}/I_{rv} = -4.649 \text{ MPa} \\f_{vrl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vrl}/I_{rv} = -4.787 \text{ MPa} \\f_{vsu1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsu} / I_{rv} = -4.854 \text{ MPa} \\f_{vsl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsl} / I_{rv} = -7.306 \text{ MPa}\end{aligned}$$

(5) 건조수축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 269069.083 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1199.871 \text{ mm}$$

$$ds2 = dv - dc2 = 299.016 \text{ mm}$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 2028994 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2434530835 \text{ N} \cdot \text{mm}$$

$$fvru2 = P2/Av + K \cdot Mv2 \cdot Yvru/lrv = 6.709 \text{ MPa}$$

$$fvrl2 = P2/Av + K \cdot Mv2 \cdot Yvrl/lrv = 6.935 \text{ MPa}$$

$$fvru2 = P2/Av + K \cdot Mv2 \cdot Yvsu/lrv = 7.044 \text{ MPa}$$

$$fvsl2 = P2/Av + K \cdot Mv2 \cdot Yvsl/lrv = 11.055 \text{ MPa}$$

(6) 온도차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 4057988 \text{ N}$$

$$Mvt = P1 \cdot dvc = 3480427843 \text{ N} \cdot \text{mm}$$

$$Ert = Es \cdot \epsilon_t = 25.200 \text{ MPa}$$

$$frut = P1/Av + K \cdot Mvt \cdot Yvru/lrv - Es \cdot \epsilon_t = -10.487 \text{ MPa}$$

$$frlt = P1/Av + K \cdot Mvt \cdot Yvrl/lrv - Es \cdot \epsilon_t = -10.163 \text{ MPa}$$

$$fsut = P1/Av + K \cdot Mvt \cdot Yvsu/lrv = 15.193 \text{ MPa}$$

$$fslt = P1/Av + K \cdot Mvt \cdot Yvsl/lrv = 20.927 \text{ MPa}$$

(7) 전단 및 비틀림

$$u = (Ss+Ssc+Sv)/Aw + (Mst/(2 F Tw)+(Msct+Mvt)/(2 Fv Tw)) = 58.662 \text{ MPa} < u_a = 110 \text{ MPa} \quad 0.K!!!$$

(8) 조합응력의 검토 (도.설 3.4.2.1)

$$i = 0.65(\phi/n)^2 + 0.13(\phi/n) + 1.0$$

$$= 0.650 \times (0.0 / 6)^2 + 0.130 \times (0.0 / 6) + 1.0 = 1.000$$

$$\therefore \phi = (f_1 - f_2) / f_1 \approx 0$$

여기서, n : 종리브에 의해서 구분되는 Pannel의 수

i : 응력구배계수 ϕ : 응력구배

f_1, f_2 : 보강된 판의 양면의 응력

(단, $f_1 \geq f_2$ 이며 압축응력을 정(+)으로 한다.)

* 인장 (상부)플랜지의 허용응력 (SM490 사용)

$$fta = 190.0 \text{ MPa}$$

* 압축 (하부)플랜지의 허용응력 (SM490 사용)

$$t_l \geq \frac{b}{24 \cdot i \cdot n} = \frac{2500}{24 \times 1.000 \times 6} = 17.361 \text{ mm}$$

인 경우 : $f_{ca} = 190.0 \text{ MPa}$

$$\frac{b}{24 \cdot i \cdot n} > t_l \geq \frac{b}{49 \cdot i \cdot n} = \frac{2500}{49 \times 1.000 \times 6} = 8.503 \text{ mm}$$

인 경우 : $f_{ca} = 190 - 3.9 (b / (t_l \cdot i \cdot n) - 24) = 225.564$

$$\frac{b}{49 \cdot i \cdot n} > t_l \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.208 \text{ mm}$$

인 경우 : $f_{ca} = 220000 \times \{ (t_l \cdot i \cdot n) / b \} = 993.485 \text{ MPa}$

사용 $t_l = 28.0 \text{ mm}$

따라서, $f_{ca} = 190.000 \text{ MPa}$

* RE-BAR의 허용응력 (도.설 2.2.2.4, 3.6.1.7)

$f_{ta} = 160.000 \text{ MPa}$ $f_{ca} = 180.000 \text{ MPa}$ (SD400 사용)

하중조합	RE-BAR			STEEL			
	작용응력 (MPa)		허용응력	작용응력 (MPa)		허용응력 (MPa)	
	상 연	하 연	(MPa)	상 연	하 연	상 연	하 연
1			160.000	-82.605	79.686	190.000	190.000
1+2+3	-72.324	-65.114	160.000	-144.259	145.693	190.000	190.000
1+2+3+4	-76.973	-69.901	160.000	-149.112	138.387	190.000	190.000
1+2+3+4+5	-70.264	-62.966	160.000	-142.068	149.442	190.000	190.000
1+2+3+4+5+6	-80.751	-73.129	184.000	-126.876	170.370	218.500	218.500
1+2+3+4+5-6	-59.777	-52.804	184.000	-157.261	128.515	218.500	218.500

주) 압축응력을 정(+), 인장응력을 부(-)로 하였음.

허용응력의 할증 (도.설 3.9.3.1 참조)

(9) 합성응력의 검토 (도.설 3.8.2.4)

(상 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{-149.112}{190.000} \right)^2 + \left(\frac{58.662}{110.000} \right)^2 \\ &= 0.616 + 0.284 = 0.900 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(하 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{149.442}{190.000} \right)^2 + \left(\frac{58.662}{110.000} \right)^2 \\ &= 0.619 + 0.284 = 0.903 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(10) 판의 최소두께 검토

인장(상부)플랜지 (도.설.기 3.8.3.1)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = 10 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K.} \quad (\text{합성형 스테드 설치})$$

압축(하부)플랜지 (도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

복부판 수평보강재 사용단수 1 단 (도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 9.9 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 79.686)} = 1.544 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = b / (219 \times 1.056) = 11.2 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 170.370)} = 1.056 < 1.2 \Rightarrow 1.056$$

(11) 항복에 대한 안전도 검사 (도.설.해(2003) 3.9.3.2)

$\Sigma f = 1.3 \times (\text{합성전 사하중 응력} + \text{합성후 사하중}) + 2.15 \times \text{활하중에 의한 응력(충격포함)}$
+ (크리프응력 변화량) + (건조수축응력변화량) + (온도차응력변화량) 의 조합 중에서
가장 불리한 하중 조합에 대하여 검토

① 상부바닥판 REBAR

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vru} = -23.554 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -72.324 - -23.554 = -48.770 \text{ MPa}$$

$$\Sigma f = 1.3 \times -23.554 + 2.15 \times -48.77 + (-4.649) + (6.709) + (-10.487) \\ = -143.903 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times -23.554 + 2.15 \times -48.77 + (-10.487) \\ = -145.962 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = -82.605 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsu} = -20.079 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -144.259 - -82.605 - -20.079 = -41.575 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-82.605 + -20.079) + 2.15 \times -41.575 + (-4.854) + (7.044) + (-15.193) \\ = -235.877 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (-82.605 + -20.079) + 2.15 \times -41.575 + (-15.193) \\ = -238.067 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = 79.686 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsl} = 21.497 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 145.693 - 79.686 - 21.497 = 44.510 \text{ MPa}$$

$$\Sigma f = 1.3 \times (79.686 + 21.497) + 2.15 \times 44.51 + (-7.306) + (11.055) + (20.927) \\ = 251.911 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

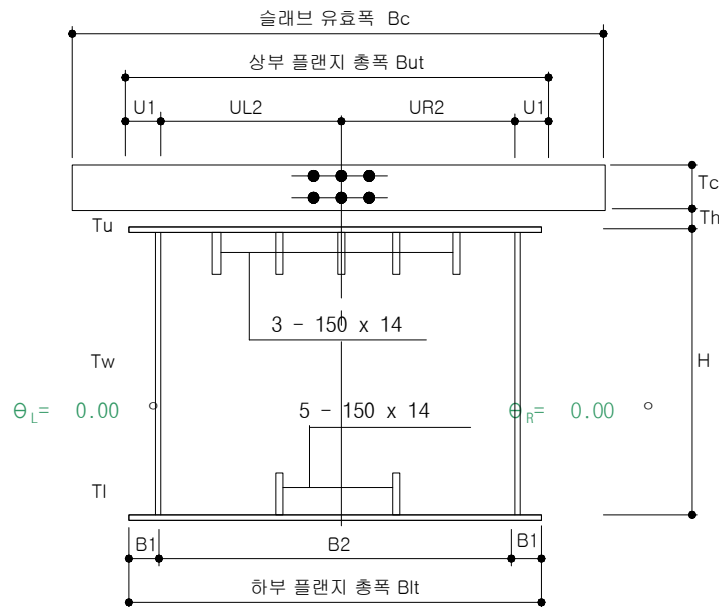
$$\Sigma f = 1.3 \times (79.686 + 21.497) + 2.15 \times 44.51 + (20.927) \\ = 248.162 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	-143.903	400.000	0.K!!!	2.77
	크리프, 건조수축제외시	-145.962	400.000	0.K!!!	2.74
상부플랜지	크리프, 건조수축 포함시	-235.877	315.000	0.K!!!	1.33
	크리프, 건조수축제외시	-238.067	315.000	0.K!!!	1.32
하부플랜지	크리프, 건조수축 포함시	251.911	315.000	0.K!!!	1.25
	크리프, 건조수축제외시	248.162	315.000	0.K!!!	1.26

5-10. 2경간 최대 부모멘트 단면검토(G2)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.600 m

Bc = 5.153 m

UL2= 1.250 , UR2= 1.250 m

B2 = 2.500 m

But= 2.700 , Bit= 2.700 m

상하 플랜지 유효폭

Bue= 2.432 , Ble= 2.432 m

Tc = 0.250 m

Th = 0.050 m

Tu = 0.028 m

Tl = 0.028 m

Tw = 0.012 m

U1 = 0.100 m

B1 = 0.100 m

RIB 150 x 14 mm , 150 x 14 mm

구 분	단 위	입력 DATA
Es : 강의 탄성계수	MPa	210000
Ec : 콘크리트의 탄성계수	MPa	26702
εs : 바닥판 콘크리트의 건조수축에 의한 최종수축율		0.00018
α : 강재 및 콘크리트의 선팽창계수		0.000012
φ2: 건조수축에 의한 크리이프계수		4
n : 강과 콘크리트의 탄성계수비		8
t : 강과 콘크리트의 온도차	℃	10
Ms : 합성전 고정하중에 의한 모멘트	kN · m	-18069.466
Msc : 합성후 고정하중에 의한 모멘트	kN · m	-4431.802
Mv : (활하중 + 지점침하)에 의한 모멘트	kN · m	-8544.392
Ss : 합성전 고정하중에 의한 전단력	kN	-1583.022
Ssc : 합성후 고정하중에 의한 전단력	kN	-376.911
Sv : (활하중 + 지점침하)에 의한 전단력	kN	-859.969
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-0.652
Mscst : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-6.040
Mvt : (활하중 + 지점침하)에 의한 비틀림모멘트	kN · m	-891.177
tcu,tcl : 교축방향 철근의 피복두께	mm	50 , 50

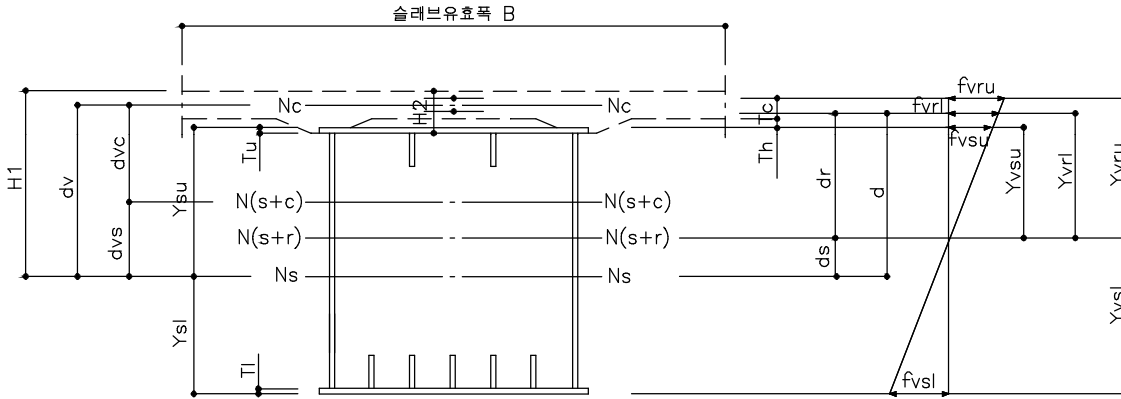
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

단 면 제 원

단 면	B(mm)	H(mm)	A(mm ²)	Y(mm)	A*Y(mm ³)	A*Y2(mm ⁴)	Ix(mm ⁴)
1 - UPPER FLANGE	2432.0	28.0	68096	1314.00	89478144	117574281216	4448939
3 - UPPER RIB	14.0	150.0	6300	1225.00	7717500	9453937500	11812500
1 - L_WEB	12.0	2600.0	31200	0.00	0	0	17576000000
1 - R_WEB	12.0	2600.0	31200	0.00	0	0	17576000000
5 - LOWER RIB	14.0	150.0	10500	-1225.00	-12862500	15756562500	19687500
1 - LOWER FLANGE	2432.0	28.0	68096	-1314.00	-89478144	117574281216	4448939
강단면 합계			215392		-5145000	260359062432	35192397877
UPPER RE-BAR	-	-	4269.90	1550.00	6618345	10258434750	-
LOWER RE-BAR	-	-	6255.90	1400.00	8758260	12261564000	-
RE-BAR 합계			10526		15376605	22519998750	-
1 - RC SLAB	5153.0	250.0	1288250	1475.00	1900168750	2802748906250	6709635417

$$* A_s = 215392 \text{ mm}^2, A_c = 1288250 \text{ mm}^2, A_r = 10526 \text{ mm}^2$$

2) 응력 검토



(1) 합 성 전

$$|s'| = A_s \cdot Y_2 + \sum |s| = 260359062432 + 35192397877 = 295551460309 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = \frac{-5145000}{215392} = -23.887 \text{ mm}$$

$$I_s = I_{s'} - A_s \cdot \delta s^2 = 295551460309 - 215392 \times -23.887^2 = 295428563335 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta_s = 2600.0 / 2 + 28.0 - -23.887 = 1351.887 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1351.887 - 2656.000 = -1304.113 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + TI/2) = 6601536.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = -82.686 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = 79.764 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot T_w) = 25.373 \text{ MPa}$$

(2) 합 성 후

$$\begin{aligned}A_v &= A_s + A_r = 225918 \text{ mm}^2 \\d &= Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1484.736 \text{ mm} \\d_r &= d \cdot A_s / (A_s + A_r) = 1415.560 \text{ mm} \\d_s &= d - d_r = 69.176 \text{ mm} \\Y_{vru} &= d_r + (T_c - t_{cu} - t_{cl}) \cdot A_{rl}/A_r = 1504.711 \text{ mm} \\Y_{vrl} &= d_r - (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1354.711 \text{ mm} \\Y_{vsu} &= Y_{vrl} - t_{cl} - T_h + T_u = 1282.711 \text{ mm} \\Y_{vsl} &= Y_{vsu} - (H + T_u + T_l) = -1373.289 \text{ mm} \\I_{rv} &= I_s + A_s \cdot d_s^2 + A_r \cdot d_r^2 = 317550979436 \text{ mm}^4 \\F_v &= b \cdot h_v = ((UL2 + UR2 + B2) / 2 + T_w) \cdot (H + (T_u + T_c/n)/2 + T_l/2) = 6640786.0 \text{ mm}^2 \\f_{vru} &= M_{sc} \cdot Y_{vru}/I_{rv} = -21.000 \text{ MPa} \\f_{vrl} &= M_{sc} \cdot Y_{vrl}/I_{rv} = -18.907 \text{ MPa} \\f_{vsu} &= M_{sc} \cdot Y_{vsu}/I_{rv} = -17.902 \text{ MPa} \\f_{vsl} &= M_{sc} \cdot Y_{vsl}/I_{rv} = 19.166 \text{ MPa} \\u &= S_{sc} / A(\text{Web}) + M_{sct} / (2 \cdot F_v \cdot T_w) = 6.078 \text{ MPa}\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}f_{vru} &= M_v \cdot Y_{vru}/I_{rv} = -40.487 \text{ MPa} \\f_{vrl} &= M_v \cdot Y_{vrl}/I_{rv} = -36.451 \text{ MPa} \\f_{vsu} &= M_v \cdot Y_{vsu}/I_{rv} = -34.514 \text{ MPa} \\f_{vsl} &= M_v \cdot Y_{vsl}/I_{rv} = 36.951 \text{ MPa} \\u &= S_v / A(\text{Web}) + M_{vt} / (2 \cdot F_v \cdot T_w) = 19.373 \text{ MPa}\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}A_{vc} &= A_s + A_c/n = 376423.250 \text{ mm}^2 \\d_v &= Y_{su} - T_u + T_h + T_c/2 = 1498.887 \text{ mm} \\d_{vc} &= d_v \cdot A_s / (A_c/n + A_s) = 857.673 \text{ mm} \\d_{vs} &= d_v - d_{vc} = 641.213 \text{ mm} \\n_1 &= n \cdot (1 + \phi_1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\A_{v1} &= A_s + A_c/n_1 = 295907.625 \text{ mm}^2 \quad \# \text{ 2차 부정정력으로 인한 영향 고려} \\d_{c1} &= d_v \cdot A_s / (A_c/n_1 + A_s) = 1091.044 \text{ mm} \quad K = -0.197 \\d_{s1} &= d_v - d_{c1} = 407.843 \text{ mm} \\I_{cv} &= I_s + I_c/n + A_s \cdot d_{vs}^2 + A_c/n \cdot d_{vc}^2 = 503281828791.6 \text{ mm}^4 \\N_c &= M_{sc} \cdot d_{vc} \cdot A_c/(n \cdot I_{cv}) = -1216189 \text{ N} \\P\phi &= N_c \cdot 2 \cdot \phi_1 / (2 + \phi_1) = -1216189 \text{ N} \\M\phi &= P\phi \cdot d_{c1} = -1326915922 \text{ N} \cdot \text{mm} \\E_{c1} &= E_c / (1 + \phi_1 / 2) = 13351 \text{ MPa} \\f_{vru1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vru}/I_{rv} = -4.145 \text{ MPa} \\f_{vrl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vrl}/I_{rv} = -4.268 \text{ MPa} \\f_{vsu1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsu} / I_{rv} = -4.327 \text{ MPa} \\f_{vsl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsl} / I_{rv} = -6.514 \text{ MPa}\end{aligned}$$

(5) 건조수축

$$n_2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$A_{v2} = A_s + A_c/n_2 = 269069.083 \text{ mm}^2$$

$$d_{c2} = d_v \cdot A_s / (A_c/n_2 + A_s) = 1199.871 \text{ mm}$$

$$d_{s2} = d_v - d_{c2} = 299.016 \text{ mm}$$

$$P_2 = E_s \cdot \epsilon_s \cdot A_c/n_2 = 2028994 \text{ N}$$

$$M_{v2} = P_2 \cdot d_{c2} = 2434530835 \text{ N} \cdot \text{mm}$$

$$f_{vru2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vru}/I_{rv} = 6.709 \text{ MPa}$$

$$f_{vrl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vrl}/I_{rv} = 6.935 \text{ MPa}$$

$$f_{vsu2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsu}/I_{rv} = 7.044 \text{ MPa}$$

$$f_{vsl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsl}/I_{rv} = 11.055 \text{ MPa}$$

(6) 온도차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P_1 = E_s \cdot \epsilon_t \cdot A_c/n = 4057988 \text{ N}$$

$$M_{vt} = P_1 \cdot d_{vc} = 3480427843 \text{ N} \cdot \text{mm}$$

$$E_{rt} = E_s \cdot \epsilon_t = 25.200 \text{ MPa}$$

$$f_{rut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vru}/I_{rv} - E_s \cdot \epsilon_t = -10.487 \text{ MPa}$$

$$f_{rlt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vrl}/I_{rv} - E_s \cdot \epsilon_t = -10.163 \text{ MPa}$$

$$f_{sut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsu}/I_{rv} = 15.193 \text{ MPa}$$

$$f_{slt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsl}/I_{rv} = 20.927 \text{ MPa}$$

(7) 전단 및 비틀림

$$u = (S_s + S_{sc} + S_v)/A_w + (M_{st}/(2 F T_w) + (M_{sct} + M_{vt})/(2 F_v T_w)) = 50.824 \text{ MPa} < u_a = 110 \text{ MPa} \quad \mathbf{0.K!!!}$$

(8) 조합응력의 검토 (도.설 3.4.2.1)

$$i = 0.65(\phi/n)^2 + 0.13(\phi/n) + 1.0$$

$$= 0.650 \times (0.0 / 6)^2 + 0.130 \times (0.0 / 6) + 1.0 = 1.000$$

$$\therefore \phi = (f_1 - f_2)/f_1 \approx 0$$

여기서, n : 종리브에 의해서 구분되는 Pannel의 수

i : 응력구배계수 ϕ : 응력구배

f_1, f_2 : 보강된 판의 양면의 응력

(단, $f_1 \geq f_2$ 이며 압축응력을 정(+)으로 한다.)

* 인장 (상부)플랜지의 허용응력 (SM490 사용)

$$f_{ta} = 190.0 \text{ MPa}$$

* 압축 (하부)플랜지의 허용응력 (SM490 사용)

$$t_l \geq \frac{b}{24 \cdot i \cdot n} = \frac{2500}{24 \times 1.000 \times 6} = 17.361 \text{ mm}$$

인 경우 : $f_{ca} = 190.0 \text{ MPa}$

$$\frac{b}{24 \cdot i \cdot n} > t_l \geq \frac{b}{49 \cdot i \cdot n} = \frac{2500}{49 \times 1.000 \times 6} = 8.503 \text{ mm}$$

인 경우 : $f_{ca} = 190 - 3.9 (b / (t_l \cdot i \cdot n) - 24) = 225.564$

$$\frac{b}{49 \cdot i \cdot n} > t_l \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.208 \text{ mm}$$

인 경우 : $f_{ca} = 220000 \times \{ (t_l \cdot i \cdot n) / b \} = 993.485 \text{ MPa}$

사용 $t_l = 28.0 \text{ mm}$

따라서, $f_{ca} = 190.000 \text{ MPa}$

* RE-BAR의 허용응력 (도.설 2.2.2.4, 3.6.1.7)

$f_{ta} = 160.000 \text{ MPa}$ $f_{ca} = 180.000 \text{ MPa}$ (SD400 사용)

하중조합	RE-BAR			STEEL			
	작용응력 (MPa)		허용응력	작용응력 (MPa)		허용응력 (MPa)	
	상 연	하 연	(MPa)	상 연	하 연	상 연	하 연
1			160.000	-82.686	79.764	190.000	190.000
1+2+3	-61.488	-55.358	160.000	-135.102	135.881	190.000	190.000
1+2+3+4	-65.632	-59.626	160.000	-139.429	129.368	190.000	190.000
1+2+3+4+5	-58.924	-52.691	160.000	-132.386	140.423	190.000	190.000
1+2+3+4+5+6	-69.410	-62.854	184.000	-117.193	161.350	218.500	218.500
1+2+3+4+5-6	-48.437	-42.528	184.000	-147.578	119.495	218.500	218.500

주) 압축응력을 정(+), 인장응력을 부(-)로 하였음.

허용응력의 할증 (도.설 3.9.3.1 참조)

(9) 합성응력의 검토 (도.설 3.8.2.4)

(상 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{-139.429}{190.000} \right)^2 + \left(\frac{50.824}{110.000} \right)^2 \\ &= 0.539 + 0.213 = 0.752 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(하 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{140.423}{190.000} \right)^2 + \left(\frac{50.824}{110.000} \right)^2 \\ &= 0.546 + 0.213 = 0.760 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(10) 판의 최소두께 검토

인장(상부)플랜지 (도.설.기 3.8.3.1)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = 10 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K.} \quad (\text{합성형 스테드 설치})$$

압축(하부)플랜지 (도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 28 \text{ mm} \quad \mathbf{0.K!!!}$$

복부판 수평보강재 사용단수 1 단 (도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 9.9 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 79.764)} = 1.543 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = b / (219 \times 1.085) = 10.9 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 161.350)} = 1.085 < 1.2 \Rightarrow 1.085$$

(11) 항복에 대한 안전도 검사 (도.설.해(2003) 3.9.3.2)

$\Sigma f = 1.3 \times (\text{합성전 사하중 응력} + \text{합성후 사하중}) + 2.15 \times \text{활하중에 의한 응력(충격포함)}$
 $+ (\text{크리프응력 변화량}) + (\text{건조수축응력변화량}) + (\text{온도차응력변화량})$ 의 조합 중에서
 가장 불리한 하중 조합에 대하여 검토

① 상부바닥판 REBAR

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vru} = -21.000 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -61.488 - 21 = -40.487 \text{ MPa}$$

$$\Sigma f = 1.3 \times -21 + 2.15 \times -40.487 + (-4.145) + (6.709) + (-10.487) \\ = -122.271 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times -21 + 2.15 \times -40.487 + (-10.487) \\ = -124.835 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = -82.686 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsu} = -17.902 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -135.102 - 82.686 - 17.902 = -34.514 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-82.686 + -17.902) + 2.15 \times -34.514 + (-4.327) + (7.044) + (-15.193) \\ = -217.446 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (-82.686 + -17.902) + 2.15 \times -34.514 + (-15.193) \\ = -220.163 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = 79.764 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsl} = 19.166 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 135.881 - 79.764 - 19.166 = 36.952 \text{ MPa}$$

$$\Sigma f = 1.3 \times (79.764 + 19.166) + 2.15 \times 36.952 + (-6.514) + (11.055) + (20.927) \\ = 233.523 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (79.764 + 19.166) + 2.15 \times 36.952 + (20.927) \\ = 228.982 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	-122.271	400.000	0.K!!!	3.27
	크리프, 건조수축제외시	-124.835	400.000	0.K!!!	3.20
상부플랜지	크리프, 건조수축 포함시	-217.446	315.000	0.K!!!	1.44
	크리프, 건조수축제외시	-220.163	315.000	0.K!!!	1.43
하부플랜지	크리프, 건조수축 포함시	233.523	315.000	0.K!!!	1.34
	크리프, 건조수축제외시	228.982	315.000	0.K!!!	1.37

6. 받침용량 검토

구분		고정하중	활하중		지점침하		거더 평균		받침용량
			MAX	MIN	MAX	MIN	MAX	MIN	
A1	SH1	1554.579	733.659	-62.787	20.957	-20.960	2266.643	1497.133	3500
	SH2	1607.626	595.499	-63.227	20.965	-20.965			3500
P1	SH1	4487.793	785.238	-113.868	62.552	-62.552	5190.916	4245.996	8000
	SH2	4350.462	630.210	-107.269	65.577	-62.575			7500
P2	SH1	4487.793	785.239	-113.868	62.552	-62.550	5189.417	4245.996	8000
	SH2	4350.462	630.210	-107.269	62.577	-62.577			7500
P3	SH1	1607.626	733.659	-62.787	20.957	-20.958	2266.643	1497.135	3500
	SH2	1554.579	595.499	-63.227	20.965	-20.963			3500

7. 현장이음부 검토

7.1 현장이음의 설계

1) SPLICE - 2 [G1]

(강종 : SM490)

(도.설.해 3.3.2.1)

휨 모멘트(kN·m)		전 단 력(kN)		총비틀림 모멘트 M_t (kN·m)	상부FL. 응력 f_u (MPa)	하부FL. 응력 f_l (MPa)	허용휨 인장응력 f_{sa} (MPa)
합성전 M_s	합성후 M_v	합성전 V_s	합성후 V_v				
13,375.34	3,533.50	79.338	20.904	356.017	80.00	-70.18	190.00

사용BOLT : H.T.B (M22 F 10T) $\rho_{sa} = 48,000 \times 2 \text{면} = 96,000 \text{ N}$ (도.설.해 3.3.2.3)

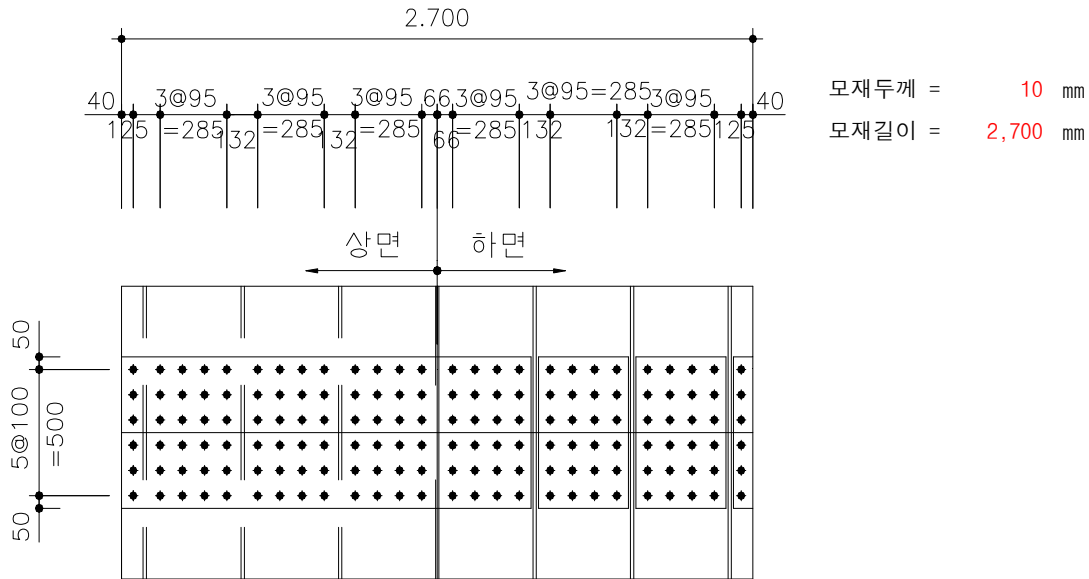
(1) 압축부 플랜지의 이음 : (상부 플랜지)

(도.설.해 3.5.3.6)

- 주요 부재의 연결은 적어도 모재의 전 강도의 75% 이상의 강도를 갖도록 설계하여야 한다. 다만, 전단력에 대해서는 작용응력을 사용하여 설계해도 좋다. (도.설.해 3.5.1.1, 3.5.3.2)

$$f_s = 79.997 \text{ MPa}$$

$$f_{s(min)} = 0.75 \times 190.0 = 142.5 \text{ MPa} \quad \therefore \text{이음부의 설계응력 (} f_u \text{) } f_s' = 142.5 \text{ MPa 적용}$$



① 필요 BOLT수의 결정

$$n_{req} = A_s \times f_s' / \rho_{sa} = 27,000.0 \times 142.5 / 96,000.0 = 41ea \Rightarrow n_t = 78ea \dots 0.K !!$$

② 이음판의 결정

- 필요 단면적 산정

$$A_{req} = A_s \times f_s' / f_{sa} = 27,000.0 \times 142.5 / 190.0 = 20,250.0 \text{ mm}^2$$

- 사용 이음판 전단면적 (A_{use})

$$1 \text{ PL} - 2,700 \times 10.0 \times 600 = 27,000.0$$

$$6 \text{ PL} - 385 \times 10.0 \times 600 = 23,100.0$$

$$2 \text{ PL} - 80 \times 10.0 \times 600 = 1,600.0$$

$$\Sigma = 51,700.0 \text{ mm}^2 \geq A_{req} \dots 0.K !!$$

- 이음판의 응력

$$f_s = A_s \times f_s' / A_{use} = 27,000.0 \times 142.5 / 51,700.0 = 74.4 \text{ MPa} \leq f_{sa} \dots 0.K !!$$

③ BOLT의 응력검토

(도.설.해 3.5.3.5)

- 축방향력 또는 전단력을 받는 판을 연결하는 경우의 BOLT 응력검토

$$\rho_n = P / n_t = 27,000.0 \times 142.5 / 78.0 = 49,326.9 \text{ N/ea} \leq \rho_{sa} \quad 0 \text{ K} !!$$

- 휨에 의한 전단력을 받는 판을 수평방향으로 연결하는 BOLT의 응력검토

Q_s, Q_v : 합성전 및 합성후의 부재 총단면의 중립축에 대한 전단력을 계산하는 접합선

외측의 단면1차 모멘트

$$Q_s = 2,700.0 \times 10.0 \times (1,415.2 - 5.0) = 3.808E+07 \text{ mm}^3$$

$$Q_v = 2,700.0 \times 10.0 \times (618.7 - 5.0) = 1.657E+07 \text{ mm}^3$$

$$I_s = 2.350E+11 \text{ mm}^4 \text{ (합성전 부재 총단면의 중립축에 대한 단면2차 모멘트)}$$

$$I_v = 4.624E+11 \text{ mm}^4 \text{ (합성후 부재 총단면의 중립축에 대한 단면2차 모멘트)}$$

$$p = \text{플랜지 전폭} / \text{횡방향 BOLT수} = 2,700.0 / 26ea = 103.8 \text{ mm (볼트의 피치)}$$

$$n = 3ea \text{ (접합선에 직각방향의 볼트의 수)}$$

$$\rho_h = (V_s \cdot Q_s / I_s + V_v \cdot Q_v / I_v) \times p / n$$

$$= (79.3 \times 38,076,318.0 / 234,951,039,018.0 + 20.9$$

$$\times 16,569,900.0 / 462,448,199,036.0) \times (103.8 / 3.0) = 471.0 \text{ N/ea}$$

- 축방향력, 휨모멘트 및 전단력이 함께 작용하는 판을 연결할 경우의 BOLT 식

$$\rho = \sqrt{(\rho_p^2 + \rho_h^2)} = \sqrt{2.433E+09 + 2.218E+05} = 49,329.2 \text{ N/ea} \leq \rho_{sa} \dots 0.K !!$$

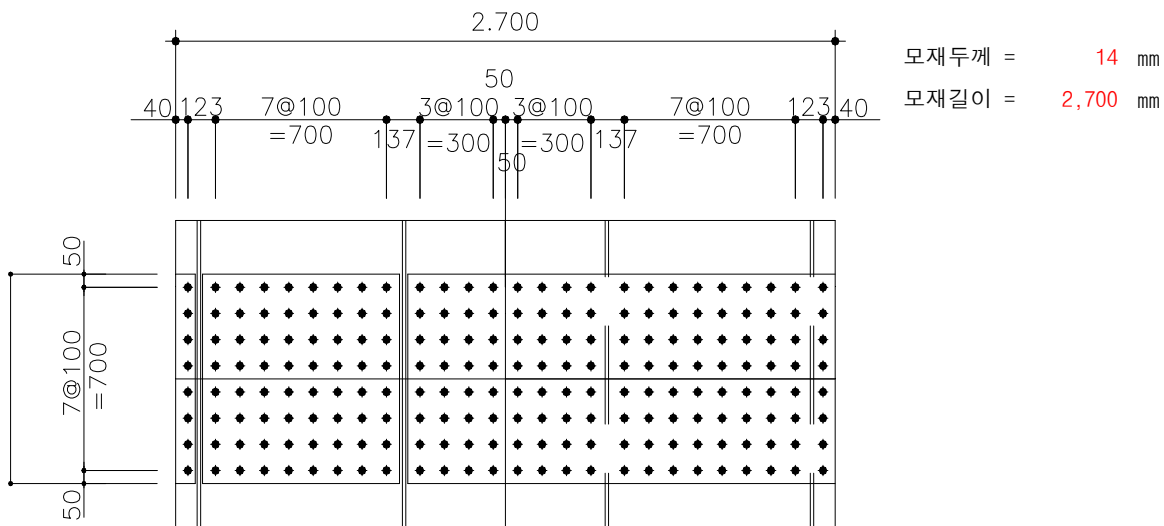
(2) 인장부 플랜지의 이음 : (하부 플랜지)

(도.설.해 3.5.3.6)

- 주요 부재의 연결은 적어도 모재의 전 강도의 75% 이상의 강도를 갖도록 설계하여야 한다. 다만, 전단력에 대해서는 작용응력을 사용하여 설계해도 좋다. (도.설.해 3.5.1.1, 3.5.3.2)

$$f_s = 70.179 \text{ MPa}$$

$$f_s' = 0.75 \times 190.0 = 142.5 \text{ MPa} \therefore \text{이음부의 설계응력 (} f_l \text{)} = 142.5 \text{ MPa 적용}$$



① 필요 BOLT수의 결정

$$n_{req} = A_s \times f_s' / \rho_{sa} = 37,800.0 \times 142.5 / 96,000.0 = 57ea \Rightarrow n_t = 104ea \dots 0.K !!$$

② 이음판의 결정

- 필요 단면적 산정

$$A_{req} = A_s \times f_s' / f_{sa} = 37,800.0 \times 142.5 / 190.0 = 28,350.0 \text{ mm}^2$$

- 사용 이음판 전단면적 A_{use}

$$1 \text{ PL} - 2,700 \times 14.0 \times 800 = 37,800.0$$

$$3 \text{ PL} - 800 \times 14.0 \times 800 = 33,600.0$$

$$2 \text{ PL} - 80 \times 14.0 \times 800 = 2,240.0$$

$$\Sigma = 73,640.0 \text{ mm}^2$$

- 이음판의 순단면적 (인장부의 순단면적은 BOLT 지름 공제) (도.설.해 3.5.3.7)

$$A_n = 73,640.0 - 25.0 \times 14.0 \times 26.0 \text{열} \times 4ea = 37,240.0 \text{ mm}^2 \geq A_{req} \dots 0.K !!$$

- 이음판의 응력

$$f_s = A_s \times f_s' / A_n = 37,800.0 \times 142.5 / 37,240.0 = 144.6 \text{ MPa} \leq f_{sa} \dots 0.K !!$$

③ BOLT의 응력검토 (도.설.해 3.5.3.5)

- 축방향력 또는 전단력을 받는 판을 연결하는 경우의 BOLT 응력검토

$$\rho_p = P / n_t = 37,800.0 \times 142.5 / 104.0 = 51,793.3 \text{ N/ea} \leq \rho_{sa} \dots 0.K !!$$

- 휨에 의한 전단력을 받는 판을 수평방향으로 연결하는 BOLT의 응력검토

Q_s, Q_v : 합성전 및 합성후의 부재 총단면의 중립축에 대한 전단력을 계산하는 접합선

외측의 단면1차 모멘트

$$Q_s = 2,700.0 \times 14.0 \times (1,208.8 - 7.0) = 4.543E+07 \text{ mm}^3$$

$$Q_v = 2,700.0 \times 14.0 \times (2,005.3 - 7.0) = 7.554E+07 \text{ mm}^3$$

$$I_s = 2.350E+11 \text{ mm}^4 \text{ (합성전 부재 총단면의 중립축에 대한 단면2차 모멘트)}$$

$$I_v = 4.624E+11 \text{ mm}^4 \text{ (합성후 부재 총단면의 중립축에 대한 단면2차 모멘트)}$$

$$p = \text{플랜지전폭/횡방향1열BOLT수} = 2,700.0 / 26ea = 103.8 \text{ mm (볼트의 피치)}$$

$$n = 4ea \text{ (접합선에 직각방향의 볼트의 수)}$$

$$\rho_h = (V_s \cdot Q_s / I_s + V_v \cdot Q_v / I_v) \times p / n$$

$$= (79.3 \times 45,426,754.8 / 234,951,039,018.0 + 20.9$$

$$\times 75,535,740.0 / 462,448,199,036.0) \times (103.8 / 4.0) = 486.9 \text{ N/ea}$$

- 축방향력, 휨모멘트 및 전단력이 함께 작용하는 판을 연결할 경우의 BOLT 식

$$\rho = \sqrt{(\rho_p^2 + \rho_h^2)} = \sqrt{2.683E+09 + 2.371E+05} = 51,795.6 \text{ N/ea} \leq \rho_{sa} \dots 0.K !!$$

④ 모재의 응력검토

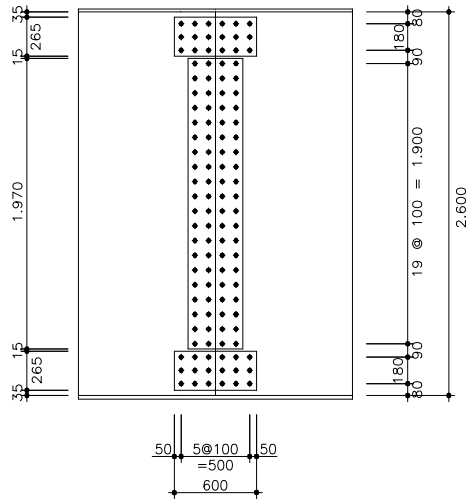
$$A_{sn} = 14.0 \times (2,700.0 - 25.0 \times 26.0) = 28,700.0 \text{ mm}^2$$

$$f_l = A_s \times f_s' / A_{sn} = 37,800.0 \times 142.5 / 28,700.0 = 187.7 \text{ MPa} \leq f_{sa} \dots 0.K !!$$

(3) WEB 연결부의 계산 : (좌측 WEB)

① BOLT의 응력계산

• 휨에 의한 BOLT의 응력



Box 평균 높이 = 2,600 mm

Box 계산 높이 = 2,600 mm

WEB 두께 = 10 mm

중립축에서 연단까지 거리 h_o = 1,300 mm

$$f_1 = f_u = 142.50 \text{ MPa}$$

$$f_2 = f_1 \cdot (h_o - 125) / h_o = 128.80 \text{ MPa}$$

$$f_3 = f_1 \cdot (h_o - 215) / h_o = 118.93 \text{ MPa}$$

$$f_4 = f_1 \cdot (h_o - 305) / h_o = 109.07 \text{ MPa}$$

$$f_5 = f_1 \cdot (h_o - 400) / h_o = 98.65 \text{ MPa}$$

$$f_6 = f_1 \cdot (h_o - 500) / h_o = 87.69 \text{ MPa}$$

$$\text{제1열 } \rho_p = (142.500 + 128.798) / 2 \times 125.0 \times 10.0 / 3ea = 56,520.4 \text{ N/ea} \leq \rho_{sa} \dots\dots 0.K !!$$

$$\text{제2열 } \rho_p = (128.798 + 118.933) / 2 \times 90.0 \times 10.0 / 3ea = 37,159.6 \text{ N/ea} \leq \rho_{sa} \dots\dots 0.K !!$$

$$\text{제3열 } \rho_p = (118.933 + 109.067) / 2 \times 90.0 \times 10.0 / 3ea = 34,200.0 \text{ N/ea} \leq \rho_{sa} \dots\dots 0.K !!$$

$$\text{제4열 } \rho_p = (109.067 + 98.654) / 2 \times 95.0 \times 10.0 / 2ea = 49,333.8 \text{ N/ea} \leq \rho_{sa} \dots\dots 0.K !!$$

$$\text{제5열 } \rho_p = (98.654 + 87.692) / 2 \times 100.0 \times 10.0 / 2ea = 46,586.5 \text{ N/ea} \leq \rho_{sa} \dots\dots 0.K !!$$

$$\sum y_i^2 = 3\text{열} \times 3846900 \times 2 + 2\text{열} \times 3275250 \times 2 = 36,182,400 \text{ mm}^2$$

$$M_w = (f_s \times t_w \times h_w^2) / 6 = (142.5 \times 10 \times 2600^2) / 6 = 1,605,500,000 \text{ Nmm} = 1,605,500 \text{ kNmm}$$

$$\rho_p = (M_w / \sum y_i^2) \times y_n = (1605500 / 36182400) \times 1300 = 57.684 \text{ kN} < 96.000 \text{ kN } 0.K!!!$$

- 전단력에 의한 BOLT의 응력 (도.설.해 3.8.2.3)

∴ 전단응력 $\tau = V / A_w + M_t / (2 \cdot F \cdot t_w)$ [비틀림 모멘트 고려시]

- 한쪽 복부판이 부담하는 전단력 : $(V_s + V_v) / 2 = (79.3 + 20.9) / 2 = 50,121.0 \text{ N}$
- 비틀림 모멘트에 의한 복부의 전단력 : $M_t / (2 \cdot b) = 356.0 / (2 \times 600) = 296,680.8 \text{ N}$

따라서, 전단력에 의한 볼트의 응력은

$$\rho_s = (50,121.0 + 296,680.8) / 58ea = 5,979.3 \text{ N/ea} \leq \rho_{sa} \dots 0.K !!$$

- 합성 응력의 검토

$$\rho = \sqrt{(\rho_p^2 + \rho_s^2)} = \sqrt{(56,520.4^2 + 5,979.3^2)} = 56,835.8 \text{ N/ea} \leq \rho_{sa} \dots 0.K !!$$

② 이음판의 응력계산

- 복부판의 단면2차 모멘트

- 합성전 단면2차 모멘트

$$I_{sw}^1 = (10.0 \times 2,600.0^3) / 12 + 10.0 \times 2,600.0 \times (1,300.0 - 1,208.8)^2 = 1.486E+10 \text{ mm}^4$$

- 합성후 단면2차 모멘트

$$I_{vw}^1 = (10.0 \times 2,600.0^3) / 12 + 10.0 \times 2,600.0 \times (2,005.3 - 1,300.0)^2 = 2.758E+10 \text{ mm}^4$$

- 복부판에 작용하는 모멘트

- 복부에 작용하는 합성전 고정하중에 의한 모멘트

$$M_{sw} = M_s \times I_{sw}^1 / I_s = 13,375.3 \times 14,863,081,378.3 \times 234,951,039,018.0 = 846.1 \text{ kN} \cdot \text{m}$$

- 복부에 작용하는 합성후 하중에 의한 모멘트

$$M_{vw} = M_v \times I_{vw}^1 / I_v = 3,533.5 \times 27,580,317,006.7 \times 462,448,199,036.0 = 210.7 \text{ kN} \cdot \text{m}$$

- 복부 이음판의 단면2차모멘트

규격	$A_s(\text{mm}^2)$	$Y(\text{mm})$	$A_s \cdot Y(\text{mm}^3)$	$A_s \cdot Y^2(\text{mm}^4)$	$I_{xo}(\text{mm}^4)$
4 - 270.0 × 10.0	10,800.0	1,265.0	1.366E+07	1.728E+10	6.561E+07
2 - 1,980.0 × 10.0	39,600.0	-	-	-	1.294E+10
합계	50,400.0	1,265.0	1.366E+07	1.728E+10	1.300E+10

$$I = I_o + AY^2 = 13,002,930,000.0 + 17,282,430,000.0 = 3.029E+10 \text{ mm}^4$$

- 합성전 단면의 중립축에 대한 이음판의 총단면2차모멘트

$$I_{sw} = 30,285,360,000.0 + 50,400.0 \times (1,300.0 - 1,208.8)^2 = 3.070E+10 \text{ mm}^4$$

- 합성후 단면의 중립축에 대한 이음판의 총단면2차모멘트

$$I_{vw} = 30,285,360,000.0 + 50,400.0 \times (2,005.3 - 1,300.0)^2 = 5.536E+10 \text{ mm}^4$$

- 이음판의 응력 검토

- 합성전 단면의 중립축에서 이음판 상·하연까지의 거리

$$y_{su} = 1,415.2 \text{ mm} \quad y_{sl} = 1,208.8 \text{ mm}$$

- 합성후 단면의 중립축에서 이음판 상·하연까지의 거리

$$y_{su,v} = 618.7 \text{ mm} \quad y_{sl,v} = 2,005.3 \text{ mm}$$

- 이음판의 상연 응력 검토

$$\begin{aligned} f_u &= (M_{sw} \cdot y_{su}) / I_{sw} + (M_{vw} \cdot y_{su,v}) / I_{vw} \\ &= (846.1 \times 1,415.2) / 30,704,871,594.9 + (210.7 \times 618.7) / 55,356,743,736.0 \\ &= 38.999 + 2.355 = 41.355 \text{ MPa} \leq f_{sa} = 190.000 \text{ MPa} \dots 0.K !! \end{aligned}$$

- 이음판의 하연 응력 검토

$$\begin{aligned} f_l &= (M_{sw} \cdot y_{sl}) / I_{sw} + (M_{vw} \cdot y_{sl,v}) / I_{vw} \\ &= (846.1 \times 1,208.8) / 30,704,871,594.9 + (210.7 \times 2,005.3) / 55,356,743,736.0 \\ &= 33.310 + 7.634 = 40.944 \text{ MPa} \leq f_{sa} = 190.000 \text{ MPa} \dots 0.K !! \end{aligned}$$

8. 피로검토 (도.설 3.3.4.1)

가) 응력반복횟수

부재 및 하중구분 도로의 종류	종방향 주부재		횡방향 부재	비 고
	트럭하중	차선하중	트럭하중	
고속도로, 국도 주간선 도로	2 백만	50 만	2 백만 이상	
기 타 도 로	10 만	10 만	50 만	

나) 허용응력 범위 fsr (MPa)

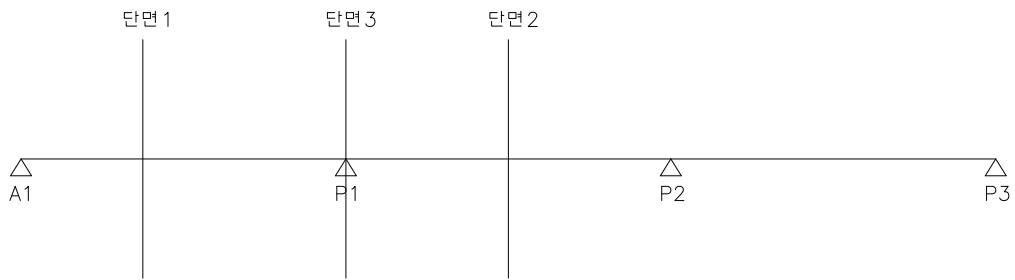
응 력 범 주	다재하 경로구조				단재하 경로구조			
	10 만회	50 만회	200 만회	200 만회이상	10 만회	50 만회	200 만회	200 만회이상
A	442	260	168	168	351	203	168	168
B	344	203	126	112	274	161	112	112
B'	274	161	101	84	218	126	77	77
C	250	147	91	70	196	112	70	63
				84*			84*	77*
D	196	112	70	49	154	91	56	35
E	154	91	56	31	119	70	42	16
E'	112	64	40	18	84	49	28	9
F	105	84	63	56	84	63	49	42

주 : * 는 거더 복부판과 플랜지의 수직보강재 용접의 경우

다) 피로조사위치 및 응력범주의 설정

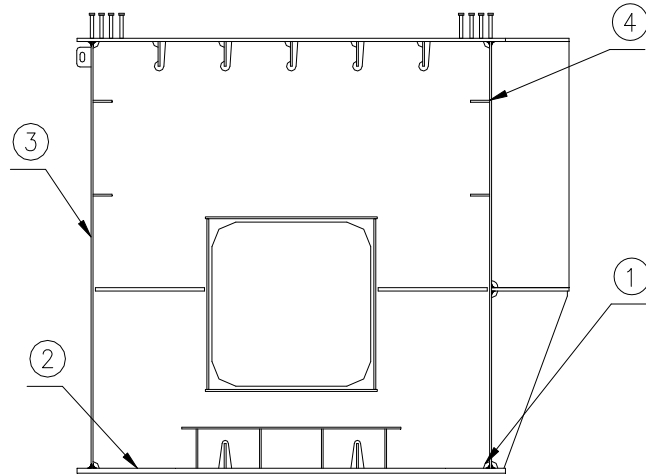
활하중에 의한 모멘트의 변동범위가 큰 단면에서 인장응력 및 교번응력이 발생하는 상세부에 대하여 피로검토를 수행 한다.

- 피로조사 단면위치



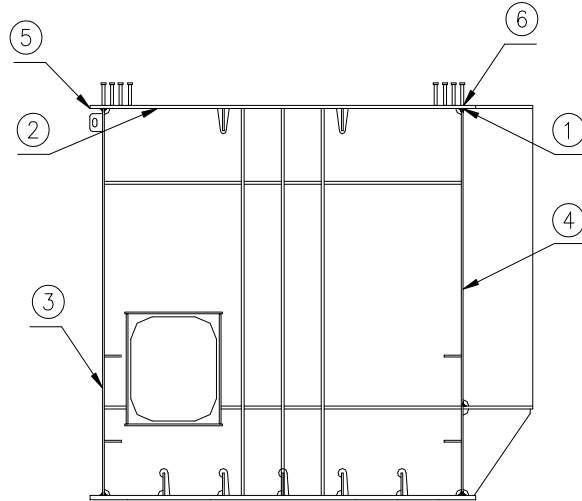
본 교량은 **고속도로** 에 속하는 **다재하경로** 구조로서 트럭하중 2백만회 와 차선하중 50만회 에 대하여 검토 하는 것으로 한다.

단면 I, II



구분	상 세	응 력 범 주	fsr (MPa)		비 고
			DB 하중	DL 하중	
①	플랜지와 복부판의 연속 필릿 용접부	B	126	203	
②	인장측 플랜지와 다이아프램의 필릿 용접부	C	91	147	
③	복부판에 부착된 가로보 연결용 거셋판 용접 끝부분	E	56	91	
④	수평보강재 용접 끝부분	E	56	91	

단면 III



구분	상 세	응 력 범 주	fsr (MPa)		비 고
			DB 하중	DL 하중	
①	플랜지와 복부판의 연속 필릿 용접부	B	126	203	
		F	63	84	전단피로검토
②	인장측 플랜지와 다이아프램의 필릿 용접부	C	91	147	
③	복부판에 부착된 가로보 연결용 거셋판 용접 끝부분	E	56	91	
④	수평보강재 용접 끝부분	E	56	91	
⑤	인장측 플랜지에 부착된 가로보 거셋판 용접 끝부분	E	56	91	
⑥	스터드에 인접한 인장측 플랜지부	C	91	147	

라) 설계피로응력

· 휨모멘트에 대한 피로검토

여기서, Δf : 설계피로응력범위 (최대응력과 최소응력의 차)

$$\Delta f = \frac{\Delta M}{I_v} y$$

$\Delta M = M_{\max} - M_{\min}$ (4.4 라.피로하중 작용범위 참조)

I_v : 합성후 단면의 단면2차 모멘트

y : 합성후 단면 도심으로부터의 거리

단면 I

구분	ΔM (KN · m)		I_v (mm ⁴)	y (mm)	Δf (MPa)		응 력 범 주	f_{sr} (MPa)		비 고
	DB 하중	DL 하중			DB 하중	DL 하중		DB 하중	DL 하중	
①	8112.688	9381.596	4.624E+11	2029	35.600	41.168	B	126	203	O.K.
②				2029	35.600	41.168	C	91	147	O.K.
③				939	16.478	19.055	E	56	91	O.K.
④				359	6.303	7.289	E	56	91	O.K.

단면 II

구분	ΔM (KN · m)		I_v (mm ⁴)	y (mm)	Δf (MPa)		응 력 범 주	f_{sr} (MPa)		비 고
	DB 하중	DL 하중			DB 하중	DL 하중		DB 하중	DL 하중	
①	7128.937	9064.272	3.515E+11	2152	43.630	55.475	B	126	203	O.K.
②				2152	43.630	55.475	C	91	147	O.K.
③				1061	21.524	27.368	E	56	91	O.K.
④				481	9.763	12.413	E	56	91	O.K.

단면 III

구분	ΔM (KN · m)		I_v (mm ⁴)	y (mm)	Δf (MPa)		응 력 범 주	f_{sr} (MPa)		비 고
	DB 하중	DL 하중			DB 하중	DL 하중		DB 하중	DL 하중	
①	5418.625	10590.712	3.173E+11	1373	23.443	45.820	B	126	203	O.K.
②				1373	23.443	45.820	C	91	147	O.K.
③				114	1.942	3.796	E	56	91	O.K.
④				431	7.359	14.383	E	56	91	O.K.
⑤				1241	21.191	41.418	E	56	91	O.K.
⑥				1255	21.430	41.885	C	91	147	O.K.

· 전단에 대한 피로검토 - 플랜지와 복부판의 필릿용접부에 대한 전단피로검토

이 부위의 피로상세범주는 "F" 이며, 검토 단면은 전단력이 가장 큰 절점 100 을 설정 하였음

$$\Delta \sigma = \frac{\Delta S \cdot Q}{I_v \cdot \sum a}$$

여기서, $\Delta \sigma$: 설계전단피로응력범위 (최대응력과 최소응력의 차)

$\Delta S = S_{max} - S_{min}$ (4.4 라.피로하중 작용범위 참조)

Q : 용접선 외측 플랜지의 총단면의 중립축에 관한

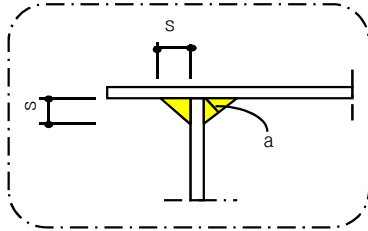
단면 1차 모멘트 ($\text{mm}^3 = A(\text{mm}^2) \cdot y(\text{mm})$)

$y = Y_{vsu}(l) - t_u(l)/2$

I_v : 합성후 단면의 단면2차 모멘트

$\sum a$: 필릿 용접의 목두께의 합 ($\text{mm} = 4EA \times s / \sqrt{2}$)

s : 필릿 용접 치수 (mm)



- 상부 플랜지와 복부판

구분	ΔS (kN)	t_u (mm)	B (mm)	A (mm^2)	Y_{vsu} (mm)	Q (mm^3)	I_v (mm^4)	s (mm)	$\sum a$ (mm)	$\Delta \sigma$ (MPa)	σ_{sr} (MPa)	비고
DB하중	1463.595	28	2500	70000	1283	8.971E+07	#####	8	22.6	18.3	63	OK
DL하중	2001.13									25.0	84	OK

- 하부 플랜지와 복부판

구분	ΔS (kN)	t_l (mm)	B (mm)	A (mm^2)	Y_{vsl} (mm)	Q (mm^3)	I_v (mm^4)	s (mm)	$\sum a$ (mm)	$\Delta \sigma$ (MPa)	σ_{sr} (MPa)	비고
DB하중	1463.595	28	2500	70000	1373	9.601E+07	#####	8	22.6	19.6	63	OK
DL하중	2001.13									26.8	84	OK