

송읍교(대구 4@55, S4~S7)-상부구조

1. 설 계 조 건

1) 교 량 제 원

- (1) 교 량 명 : 송읍교(대구)
 (3) 교 량 형 식 : Steel Box Girder교
 (4) 교 량 연 장 : 4@55 = 220.0m
 (5) 교 량 폭 원 : B = 12.145 m
 (7) 사 각(Skew) : 90.000 °
 (6) Girder 제 원 : B = 2.500 m H = 2.700 m
 (2) 교 량 등 급 : 1 등급 (DB-24 및 DL-24 적용)

(10) 사용재료 및 물리적 특성치

① 강 재

▪ 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)	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)			
	축방향 인장응력 및 휨 인장응력							

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)

(199 도.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

$$W_c = 11.405 \text{ m}, N = 3 \text{ 차로}$$

$$W = 11.405 / 3 = 3.802 \text{ m} > 3.600 \text{ m}$$

∴ 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

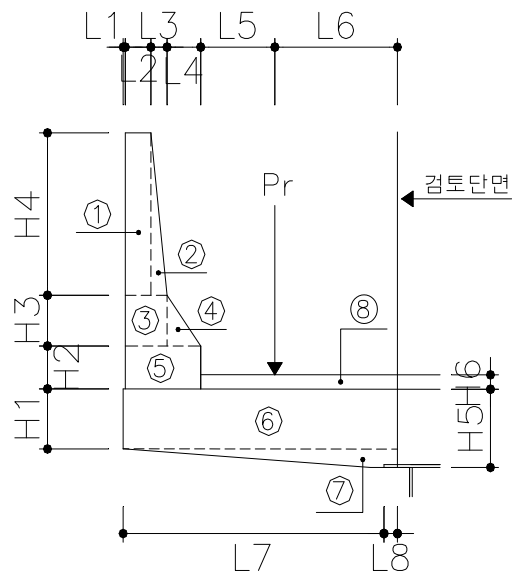
- (1) 바 닥 판 : 강도설계법
- (2) Steel Box Girder : 허용응력 설계법

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 =	0.200 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	$1.025 \times 0.25 \times 25 = 4.400$	0.440	1.936
7	$\frac{1}{2} \times 0.880 \times 0.100 \times 25 = 1.100$	0.293	0.323
8	$0.08 \times 0.595 \times 23 = 1.095$	0.298	0.326
TOTAL	9.821		5.116

$$\therefore M_d = 5.116 \text{ kN} \cdot \text{m}$$

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 H는 노면상 1.0m 높이에 교축을 따라 1.0m마다 작용시

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

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

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

$$\begin{aligned} \textcircled{1} \quad Mu1 &= 1.3 \text{ Md} + 2.15 \text{ MI}+i \\ &= 1.3 \times 5.116 + 2.15 \times 26.756 = 64.177 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{2} \quad Mu2 &= 1.3 \text{ Md} + 1.3 \text{ MI}+i + 1.3 \text{ Mco} \\ &= 1.3 \times 5.116 + 1.3 \times 26.756 + 1.3 \times 32.5 = 83.684 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{3} \quad Mu3 &= 1.3 \text{ Md} + 1.3 \text{ MI}+i + 0.65 \text{ Mw} \\ &= 1.3 \times 5.116 + 1.3 \times 26.756 + 0.65 \times 2.695 = 43.186 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{4} \quad Mu4 &= 1.2 \text{ Md} + 1.2 \text{ Mw} + 1.2 \text{ Mco} \\ &= 1.2 \times 5.116 + 1.2 \times 2.695 + 1.2 \times 32.5 = 48.374 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{5} \quad Mu5 &= 1.3 \text{ Md} + 1.3 \text{ Mw} \\ &= 1.3 \times 5.116 + 1.3 \times 2.695 = 10.155 \text{ kN} \cdot \text{m/m} \end{aligned}$$

사용 모멘트

$$\begin{aligned} M &= 1.0 \text{ Md} + 1.0 \text{ MI}+i + 0.3 \text{ Mw} \\ &= 1.0 \times 5.116 + 1.0 \times 26.756 + 0.3 \times 2.695 = 32.681 \text{ kN} \cdot \text{m/m} \end{aligned}$$

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]

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

$$M_u = 83.684 \text{ kN} \cdot \text{m}$$

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

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

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

[Req'd d & As]

(콘.설 6.3.2)

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

$$M_u = \phi \times A_s \times f_y \times (d - a/2) = -3.0 A_s^2 + 85000 A_s$$
$$= 83684000$$

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

O.K.!!

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

$$\therefore \text{Req'd } A_s = 1020.8 \text{ mm}^2$$

$$\text{Min. } A_s = \text{Req'd } A_s \times 4/3 = 1361.1 \text{ mm}^2$$

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

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

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

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

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

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]

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

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

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

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

$$\phi M_n = \phi f_y \times A_s \times j d = 127.569 \text{ kN} \cdot \text{m} > M_u = 83.684 \text{ kN} \cdot \text{m} \quad \mathbf{O.K.}$$

아) 사용성(균열) 검토

$$M_{\max} = 32.681 \text{ kN} \cdot \text{m/m}$$

$$\text{탄성계수비}(n) = 7$$

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

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

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

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

$$\begin{aligned} f_{s\max} &= \frac{M_{\max}}{p b j d^2} = \frac{32.681 \times 1000000}{0.0064 \times 1000 \times 0.914 \times 250^2} \\ &= 89.390 \text{ MPa} < 0.6 f_y = 240.000 \text{ MPa} \quad \mathbf{O.K!!} \end{aligned}$$

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

$$\text{인장연단폭}(S_1) = 375 (210 / f_s) - 2.5 C_c = 375 (210 / 89.39) - 2.5 \times 42 = 779.721 \text{ mm}$$

$$\text{인장연단폭}(S_2) = 300 (210 / f_s) = 300 (210 / 89.39) = 704.777 \text{ mm}$$

$$\text{철근 소요중심간격}(S_a) = \text{Min} (S_1, S_2) = 704.777 \text{ mm}$$

$$\text{철근 평균간격 } S = 125.0 \text{ mm} \leq 704.777 \text{ mm} \quad \mathbf{O.K!!}$$

1-2. 중앙부

가) 고정하중

$$\begin{aligned}
 \text{철근콘크리트 : } & 0.300 \text{ m} \times 25.000 \text{ kN/m}^3 = 7.500 \text{ kN/m}^2 \\
 \text{포장 : } & 0.080 \text{ m} \times 23.000 \text{ kN/m}^3 = 1.840 \text{ kN/m}^2 \\
 \hline
 & W_d = 9.340 \text{ kN/m}^2 \\
 \text{계산지간 } L = & 2.450 \text{ m} \quad \text{바닥판 지점의 수 } n = 5 \\
 M_d = (1/10) \cdot W_d \cdot L^2 = & (1/10) \times 9.34 \times 2.45^2 = 5.606 \text{ kN} \cdot \text{m}
 \end{aligned}$$

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

충격계수 (도.설 2.1.4)

$$i = 15 / (40 + L) = 15 / (40 + 2.45) = 0.353 > 0.3 \therefore i = 0.3$$

$$\begin{aligned}
 M_{I+i} &= ((L+0.6) / 9.6) \cdot P_r \cdot (1+i) = ((2.45 + 0.6) / 9.6) \times 96 \times (1 + 0.3) \\
 &= 39.650 \text{ kN} \cdot \text{m}
 \end{aligned}$$

연속바닥판이므로, (도.설 3.6.1.4)

$$M_{I+i} = 0.8 \times 39.65 = 31.720 \text{ kN} \cdot \text{m/m}$$

다) 하중 조합 (도.설 2.2.3.2)

① 계수 모멘트

$$\begin{aligned}
 M_{u1} &= 1.3 M_d + 2.15 M_{I+i} \\
 &= 1.3 \times 5.606 + 2.15 \times 31.72 = 75.486 \text{ kN} \cdot \text{m/m}
 \end{aligned}$$

① 사용 모멘트

$$\begin{aligned}
 M &= 1.0 M_d + 1.0 M_{I+i} \\
 &= 1.0 \times 5.606 + 1.0 \times 31.72 = 37.326 \text{ kN} \cdot \text{m/m}
 \end{aligned}$$

라) 바닥판의 최소 두께 (도.설 3.6.1.5)

$$h_{min} = (30 \cdot L + 130) = \{(30 \times 2.45) + 130\} = 204 \text{ mm}$$

$$h_{use} = 300.0 \text{ mm} > 204.0 \text{ mm} \quad \mathbf{O.K!!}$$

마) 단면검토

◀ 철근량 산정

① 캔틸레버부

[DESIGN CONDITION]

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

$$M_u = 75.486 \text{ kN} \cdot \text{m}$$

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

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

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

[Req'd d & As]

(콘.설 6.3.2)

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

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

$$= 75486000$$

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

0.K.!!

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

$$\therefore \text{Req'd } A_s = 917.4 \text{ mm}^2$$

$$\text{Min. } A_s = \text{Req'd } A_s \times 4/3 = 1223.2 \text{ mm}^2$$

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

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

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

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

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

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]

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

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

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

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

$$\Phi M_n = \Phi f_y \times A_s \times jd = 127.569 \text{ kN} \cdot \text{m} > M_u = 75.486 \text{ kN} \cdot \text{m} \quad \mathbf{0.K.}$$

아) 사용성(균열) 검토

$$M_{\max} = 37.326 \text{ kN} \cdot \text{m/m}$$

$$\text{탄성계수비}(n) = E_s / E_c = 7$$

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

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

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

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

$$\begin{aligned} f_{s\max} &= \frac{M_{\max}}{p b j d^2} = \frac{37.326 \times 1000000}{0.0064 \times 1000 \times 0.914 \times 250^2} \\ &= 102.095 \text{ MPa} < 0.6 f_y = 240.000 \text{ MPa} \quad \mathbf{0.K!!} \end{aligned}$$

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

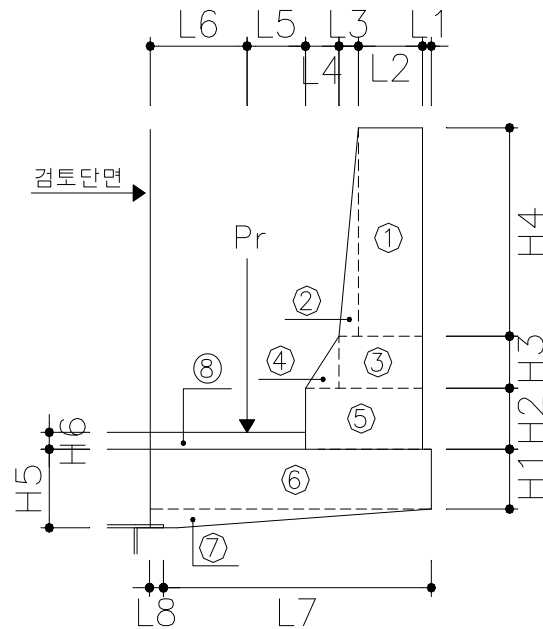
$$\text{인장연단폭}(S_1) = 375 (210 / f_s) - 2.5 C_c = 375 (210 / 102.095) - 2.5 \times 42 = 670.090 \text{ mm}$$

$$\text{인장연단폭}(S_2) = 300 (210 / f_s) = 300 (210 / 102.095) = 617.072 \text{ mm}$$

$$\text{철근 소요중심간격}(S_a) = \text{Min} (S_1, S_2) = 617.072 \text{ mm}$$

$$\text{철근 평균간격 } S = 125.0 \text{ mm} \leq 617.072 \text{ mm} \quad \mathbf{0.K!!}$$

1-3. 우측 캔틸레버부



콘크리트 단위중량	: 25.000 kN/m ³	H1 =	0.200 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 (k N)	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	$0.870 \times 0.25 \times 25 = 4.350$	0.435	1.892
7	$\frac{1}{2} \times 0.870 \times 0.05 \times 25 = 1.088$	0.290	0.315
8	$0.08 \times 0.420 \times 23 = 0.773$	0.210	0.162
TOTAL	13.735		7.511

$$\therefore Md = 7.511 \text{ kN} \cdot \text{m}$$

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

$$\begin{aligned} \textcircled{1} \quad Mu_1 &= 1.3 M_d + 2.15 Ml+i \\ &= 1.3 \times 7.511 + 2.15 \times 12.117 = 35.816 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{2} \quad Mu_2 &= 1.3 M_d + 1.3 Ml+i + 1.3 M_{co} \\ &= 1.3 \times 7.511 + 1.3 \times 12.117 + 1.3 \times 32.5 = 67.767 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{3} \quad Mu_3 &= 1.3 M_d + 1.3 Ml+i + 0.65 M_w \\ &= 1.3 \times 7.511 + 1.3 \times 12.117 + 0.65 \times 3.524 = 27.807 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{4} \quad Mu_4 &= 1.2 M_d + 1.2 M_w + 1.2 M_{co} \\ &= 1.2 \times 7.511 + 1.2 \times 3.524 + 1.2 \times 32.5 = 52.243 \text{ kN} \cdot \text{m/m} \end{aligned}$$

$$\begin{aligned} \textcircled{5} \quad Mu_5 &= 1.3 M_d + 1.3 M_w \\ &= 1.3 \times 7.511 + 1.3 \times 3.524 = 14.346 \text{ kN} \cdot \text{m/m} \end{aligned}$$

사용 모멘트

$$\begin{aligned} M &= 1.0 M_d + 1.0 Ml+i + 0.3 M_w \\ &= 1.0 \times 7.511 + 1.0 \times 12.117 + 0.3 \times 3.524 = 20.685 \text{ kN} \cdot \text{m/m} \end{aligned}$$

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]

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

$$M_u = 67.767 \text{ kN} \cdot \text{m}$$

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

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

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

[Req'd d & As]

(콘.설 6.3.2)

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

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

$$= 67767000$$

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

O.K.!!

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

$$\therefore \text{Req'd } A_s = 820.7 \text{ mm}^2$$

$$\text{Min. } A_s = \text{Req'd } A_s \times 4/3 = 1094.3 \text{ mm}^2$$

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

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

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

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

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

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]

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

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

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

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

$$\phi M_n = \phi f_y \times A_s \times j_d = 127.569 \text{ kN} \cdot \text{m} > M_u = 67.767 \text{ kN} \cdot \text{m} \quad \mathbf{O.K.}$$

아) 사용성(균열) 검토

$$M_{\max} = 20.685 \text{ kN} \cdot \text{m/m}$$

$$\text{탄성계수비}(n) = 7$$

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

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

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

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

$$\begin{aligned} f_{s\max} &= \frac{M_{\max}}{p b j d^2} = \frac{20.685 \times 1000000}{0.0064 \times 1000 \times 0.914 \times 250.0^2} \\ &= 56.578 \text{ MPa} < 0.6 f_y = 240.000 \text{ MPa} \quad \mathbf{O.K!!} \end{aligned}$$

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

$$\text{인장연단폭}(S_1) = 375 (210 / f_s) - 2.5 C_c = 375 (210 / 56.578) - 2.5 \times 42 = 1290.634 \text{ mm}$$

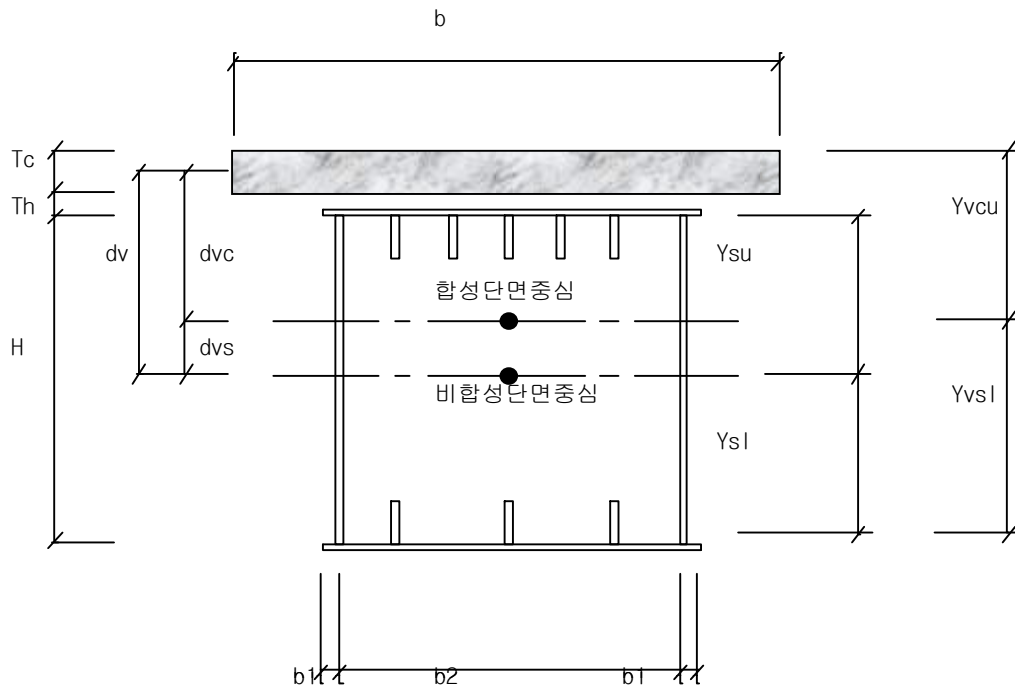
$$\text{인장연단폭}(S_2) = 300 (210 / f_s) = 300 (210 / 56.578) = 1113.507 \text{ mm}$$

$$\text{철근 소요중심간격}(S_a) = \text{Min} (S_1, S_2) = 1113.507 \text{ mm}$$

$$\text{철근 평균간격 } S = 125.0 \text{ mm} \leq 1113.507 \text{ mm} \quad \mathbf{O.K!!}$$

2. 단면상수 산정

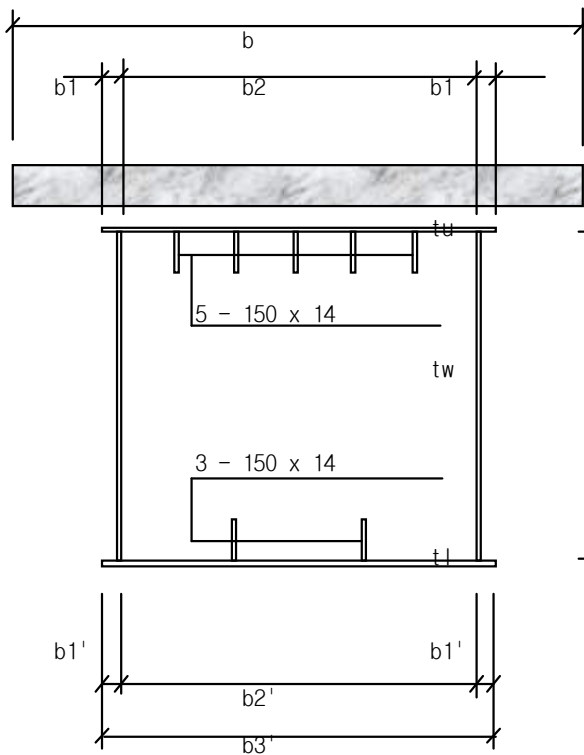
2-1. Steel Box 주형 단면상수 산정



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	=	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	=	200.000	mm
Th	=	50.000	mm
H	=	2700.000	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	1355.00	36585000	49572675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 10.0	27000	-1355.00	-36585000	49572675000	225000
TOTAL		135600		5355000	126455850000	39397950000

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

$$= 126455850000 + 39397950000 = 165853800000 \text{ mm}^4$$

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

$$= 5355000 / 135600 = 39.49 \text{ mm}$$

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

$$= 165853800000 - 135600 \times 39.491^2 = 165642324889 \text{ mm}^4$$

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

$$= (2700^3 \times 10 / 12) + (2700^3 \times 10 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 135030110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 10.000 / 2 = 2710.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2710^2) / (2 \times 2710/12 + 2512/10 + 2512/10) \\
&= 194293879745 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

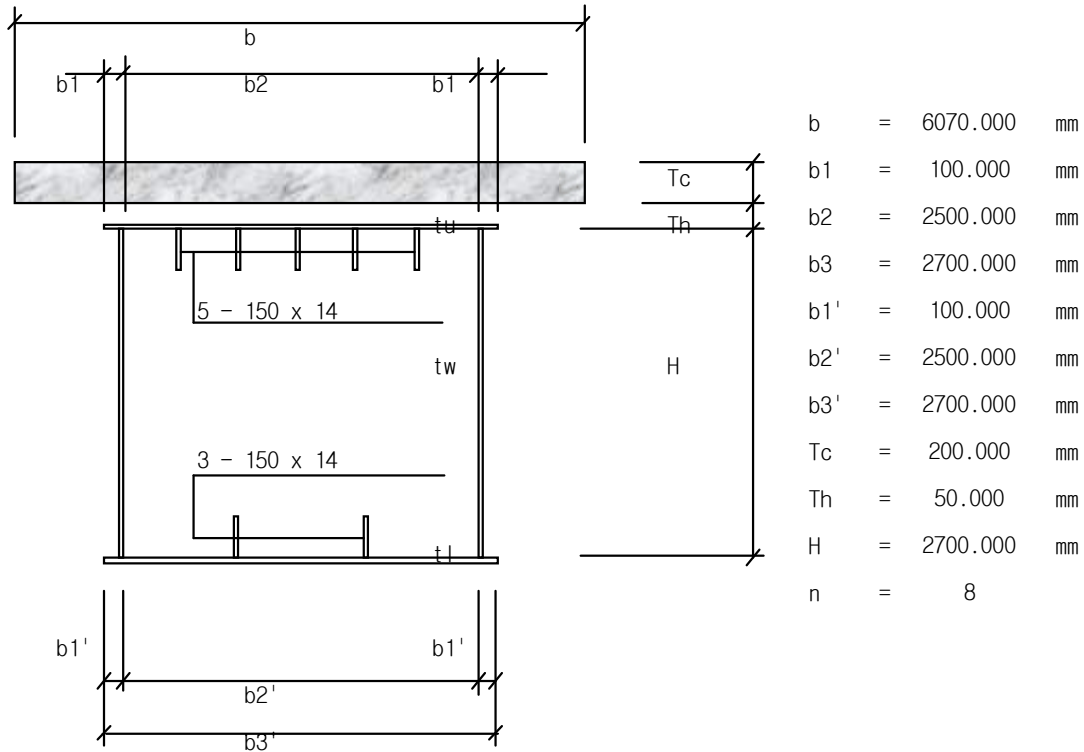
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 135600 + 1214000 / 8 = 287350 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 39.491 + 50.000 + 200.000 / 2 = 1460.51 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1460.509 \times 135600 / 287350 = 689.21 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1460.509 - 689.212 = 771.30 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 165642324889 + 4046666667 / 8 + 135600 \times 771.297^2 \\
&\quad + 1214000 / 8 \times 689.212^2 = 318899689798 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 135030110400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 600964574983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2710^2) / (2 \times 2710/12 + 2512/35 + 2512/10) \\
&= 239297957770 \text{ mm}^4
\end{aligned}$$

- Section G1-2



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	1356.00	43934400	59575046400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 10.0	27000	-1355.00	-36585000	49572675000	225000
TOTAL		141000		12704400	136458221400	39398113800

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

$$= 136458221400 + 39398113800 = 175856335200 \text{ mm}^4$$

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

$$= 12704400 / 141000 = 90.10 \text{ mm}$$

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

$$= 175856335200 - 141000 \times 90.10^2 = 174711641729 \text{ mm}^4$$

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

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

$$= 138310610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 12.000 / 2 + 10.000 / 2 = 2711.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/12 + 2512/10) \\
&= 203324113146 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

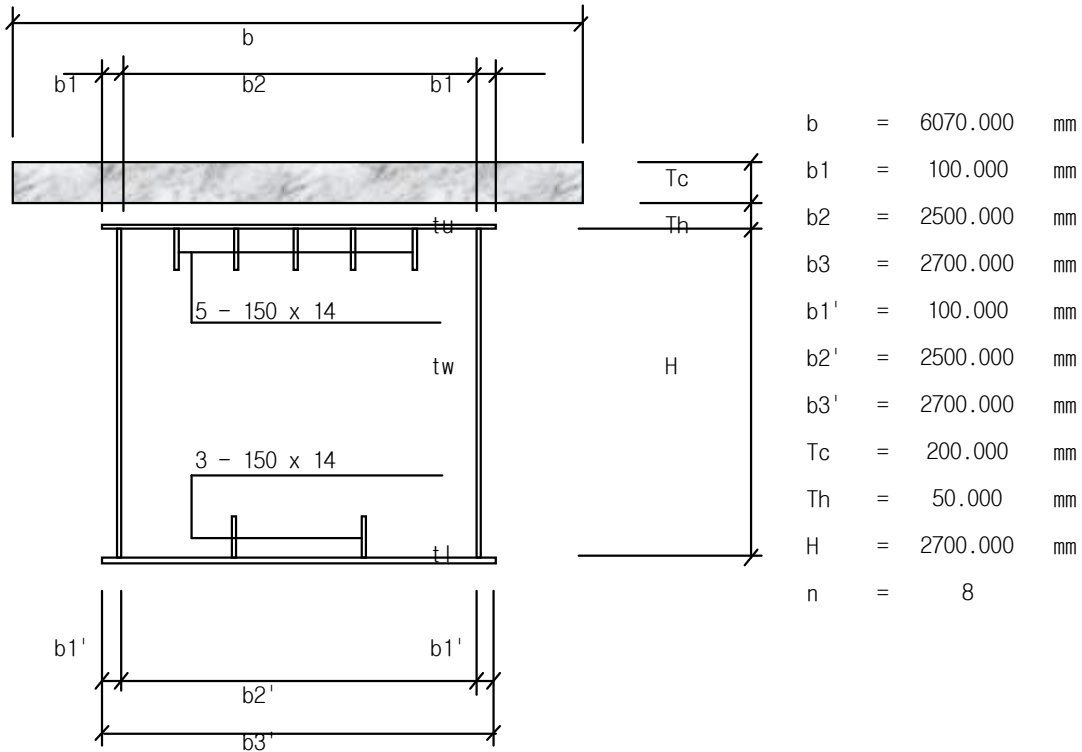
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 141000 + 1214000 / 8 = 292750 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 90.102 + 50.000 + 200.000 / 2 = 1409.90 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1409.898 \times 141000 / 292750 = 679.06 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1409.898 - 679.063 = 730.84 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 174711641729 + 4046666667 / 8 + 141000 \times 730.835^2 \\
&\quad + 1214000 / 8 \times 679.063^2 = 320504295333 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 138310610400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 604245074983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 200.000 / 8 = 37.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/37 + 2512/10) \\
&= 240627932897 \text{ mm}^4
\end{aligned}$$

- 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	1356.00	43934400	59575046400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1357.00	-51294600	69606772200	617400
TOTAL		151800		-2005200	156492318600	39398506200

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

$$= 156492318600 + 39398506200 = 195890824800 \text{ mm}^4$$

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

$$= -2005200 / 151800 = -13.21 \text{ mm}$$

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

$$= 195890824800 - 151800 \times (-13.209)^2 = 195864337138 \text{ mm}^4$$

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

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

$$= 144871610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 12.000 / 2 + 14.000 / 2 = 2713.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2713^2) / (2 \times 2713/12 + 2512/12 + 2512/14) \\
&= 220922393940 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

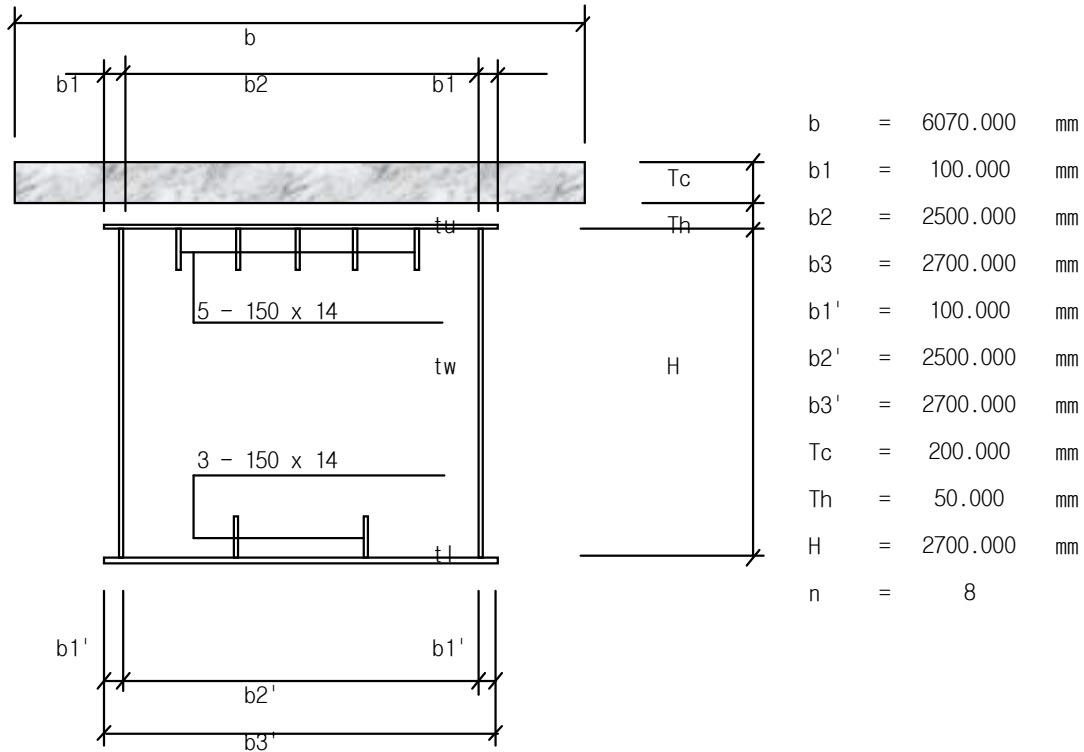
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 151800 + 1214000 / 8 = 303550 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 13.209 + 50.000 + 200.000 / 2 = 1513.21 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1513.209 \times 151800 / 303550 = 756.73 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1513.209 - 756.729 = 756.48 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 195864337138 + 4046666667 / 8 + 151800 \times 756.480^2 \\
&\quad + 1214000 / 8 \times 756.729^2 = 370137587051 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 144871610400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 610806074983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 200.000 / 8 = 37.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2713^2) / (2 \times 2713/12 + 2512/37 + 2512/14) \\
&= 265594526573 \text{ mm}^4
\end{aligned}$$

- Section G1-4



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 16.0	43200	1358.00	58665600	79667884800	921600
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1357.00	-51294600	69606772200	617400
TOTAL		162600		12726000	176585157000	39399039000

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

$$= 176585157000 + 39399039000 = 215984196000 \text{ mm}^4$$

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

$$= 12726000 / 162600 = 78.27 \text{ mm}$$

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

$$= 215984196000 - 162600 \times 78.266^2 = 214988186923 \text{ mm}^4$$

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

$$= (2700^3 \times 16 / 12) + (2700^3 \times 14 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 151432610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 16.000 / 2 + 14.000 / 2 = 2715.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2715^2) / (2 \times 2715/12 + 2512/16 + 2512/14) \\
&= 235831191268 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

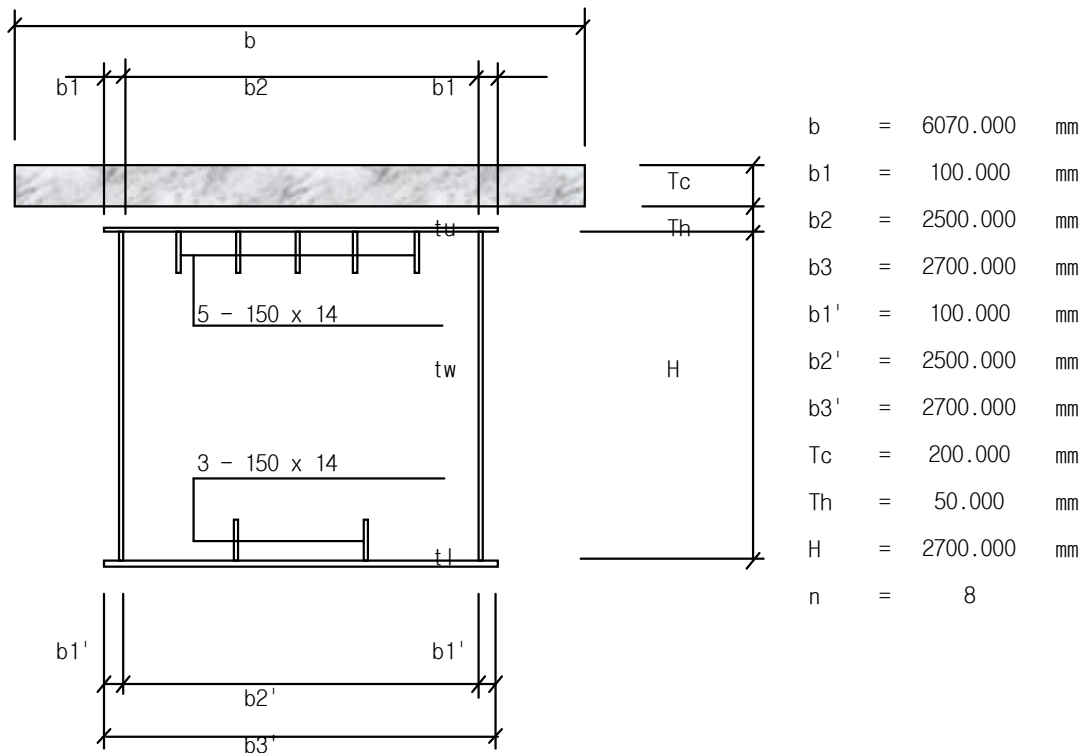
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 162600 + 1214000 / 8 = 314350 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 78.266 + 50.000 + 200.000 / 2 = 1421.73 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1421.734 \times 162600 / 314350 = 735.40 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1421.734 - 735.403 = 686.33 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 214988186923 + 4046666667 / 8 + 162600 \times 686.331^2 \\
&\quad + 1214000 / 8 \times 735.403^2 = 374155926976 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 151432610400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 617367074983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 16.000 + 200.000 / 8 = 41.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2715^2) / (2 \times 2715/12 + 2512/41 + 2512/14) \\
&= 268399893967 \text{ mm}^4
\end{aligned}$$

- Section G1-5



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	1358.00	58665600	79667884800	921600
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 20.0	54000	-1360.00	-73440000	99878400000	1800000
TOTAL		178800		-9419400	206856784800	39400221600

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

$$= 206856784800 + 39400221600 = 246257006400 \text{ mm}^4$$

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

$$= -9419400 / 178800 = -52.68 \text{ mm}$$

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

$$= 246257006400 - 178800 \times (-52.68)^2 = 245760781029 \text{ mm}^4$$

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

$$= (2700^3 \times 16 / 12) + (2700^3 \times 20 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 161274110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 16.000 / 2 + 20.000 / 2 = 2718.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2718^2) / (2 \times 2718/12 + 2512/16 + 2512/20) \\
&= 253487440149 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

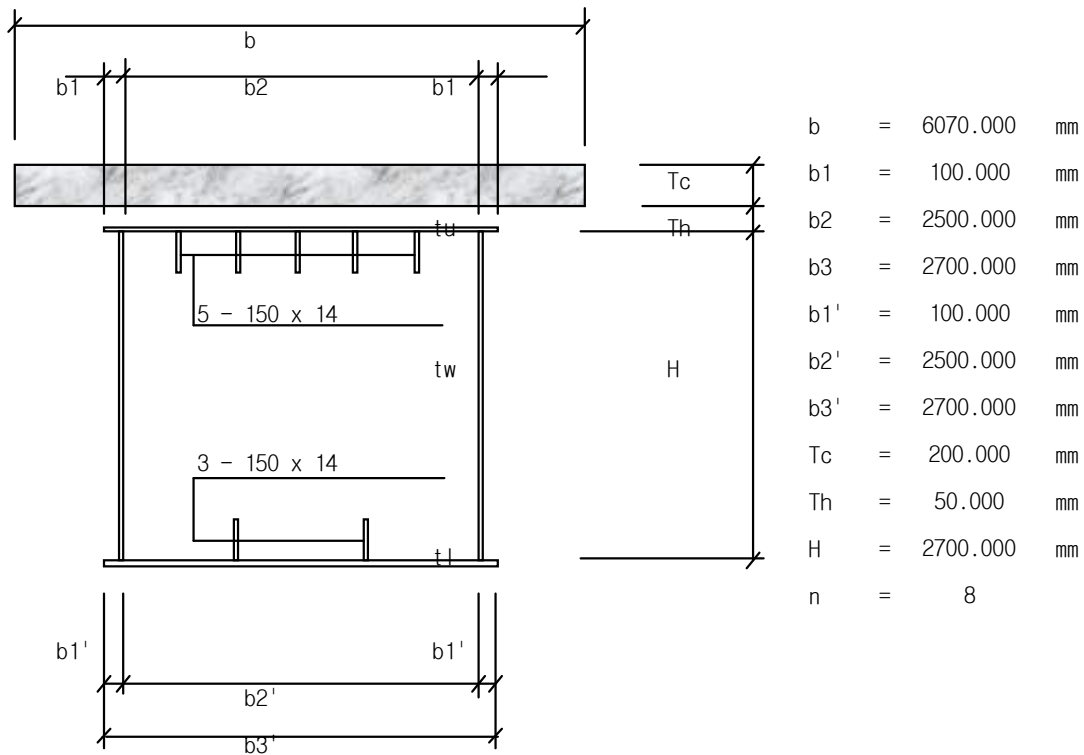
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c / N \\
&= 178800 + 1214000 / 8 = 330550 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 52.681 + 50.000 + 200.000 / 2 = 1552.68 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1552.681 \times 178800 / 330550 = 839.87 \text{ mm} \\
dvs &= dv - dvc = 1552.681 - 839.871 = 712.81 \text{ mm} \\
I_{v33} &= I_{33} + I_c / N + \sum A_s \cdot dvs^2 + A_c / N \cdot dvc^2 \\
&= 245760781029 + 4046666667 / 8 + 178800 \times 712.810^2 \\
&\quad + 1214000 / 8 \times 839.871^2 = 444156522243 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 161274110400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 627208574983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 16.000 + 200.000 / 8 = 41.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2718^2) / (2 \times 2718/12 + 2512/41 + 2512/20) \\
&= 291412096999 \text{ mm}^4
\end{aligned}$$

- Section G1-6



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	1356.00	43934400	59575046400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 20.0	54000	-1360.00	-73440000	99878400000	1800000
TOTAL		168000		-24150600	186763946400	39399688800

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

$$= 186763946400 + 39399688800 = 226163635200 \text{ mm}^4$$

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

$$= -24150600 / 168000 = -143.75 \text{ mm}$$

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

$$= 226163635200 - 168000 \times (-143.75)^2 = 222691900198 \text{ mm}^4$$

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

$$= (2700^3 \times 12 / 12) + (2700^3 \times 20 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 154713110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 12.000 / 2 + 20.000 / 2 = 2716.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/12 + 2512/20) \\
&= 236403055350 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

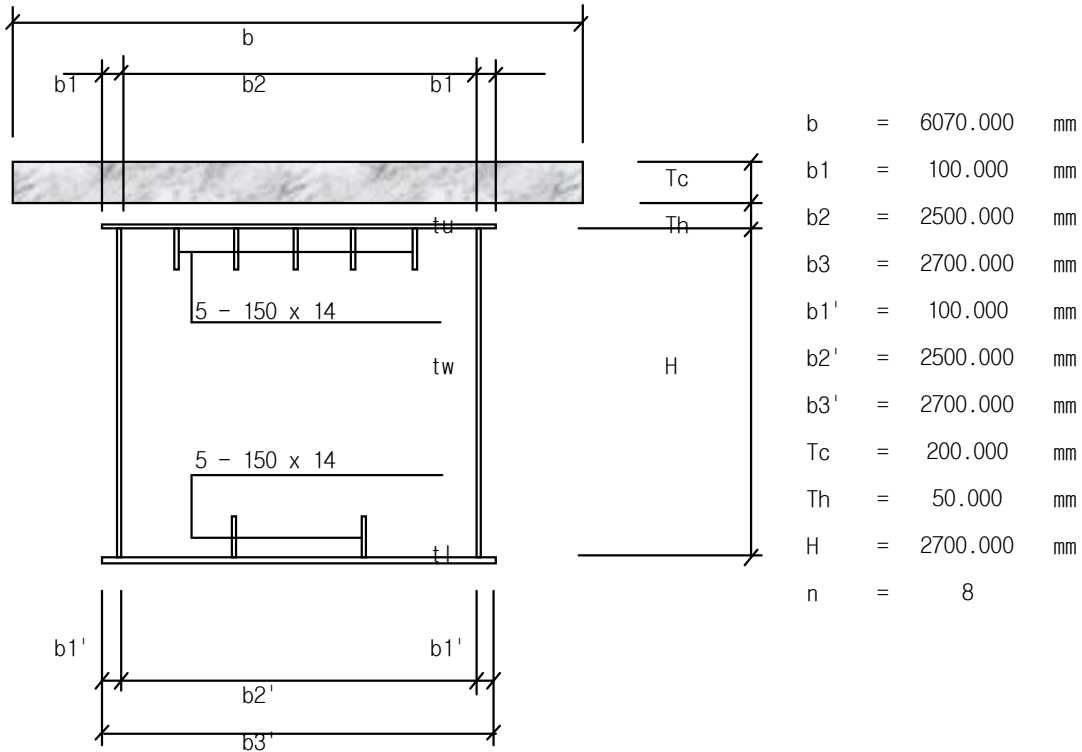
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 168000 + 1214000 / 8 = 319750 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 143.754 + 50.000 + 200.000 / 2 = 1643.75 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1643.754 \times 168000 / 319750 = 863.65 \text{ mm} \\
dvs &= dv - dvc = 1643.754 - 863.645 = 780.11 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 222691900198 + 4046666667 / 8 + 168000 \times 780.108^2 \\
&\quad + 1214000 / 8 \times 863.645^2 = 438625087516 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 154713110400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 620647574983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 200.000 / 8 = 37.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/37 + 2512/20) \\
&= 288150708410 \text{ mm}^4
\end{aligned}$$

- 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 12.0	32400	1356.00	43934400	59575046400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1357.00	-51294600	69606772200	617400
TOTAL		156000		-7360200	163319943600	39406381200

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

$$= 163319943600 + 39406381200 = 202726324800 \text{ mm}^4$$

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

$$= -7360200 / 156000 = -47.18 \text{ mm}$$

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

$$= 202726324800 - 156000 \times (-47.18)^2 = 202379064902 \text{ mm}^4$$

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

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

$$= 144871610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 12.000 / 2 + 14.000 / 2 = 2713.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2713^2) / (2 \times 2713/12 + 2512/12 + 2512/14) \\
&= 220922393940 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

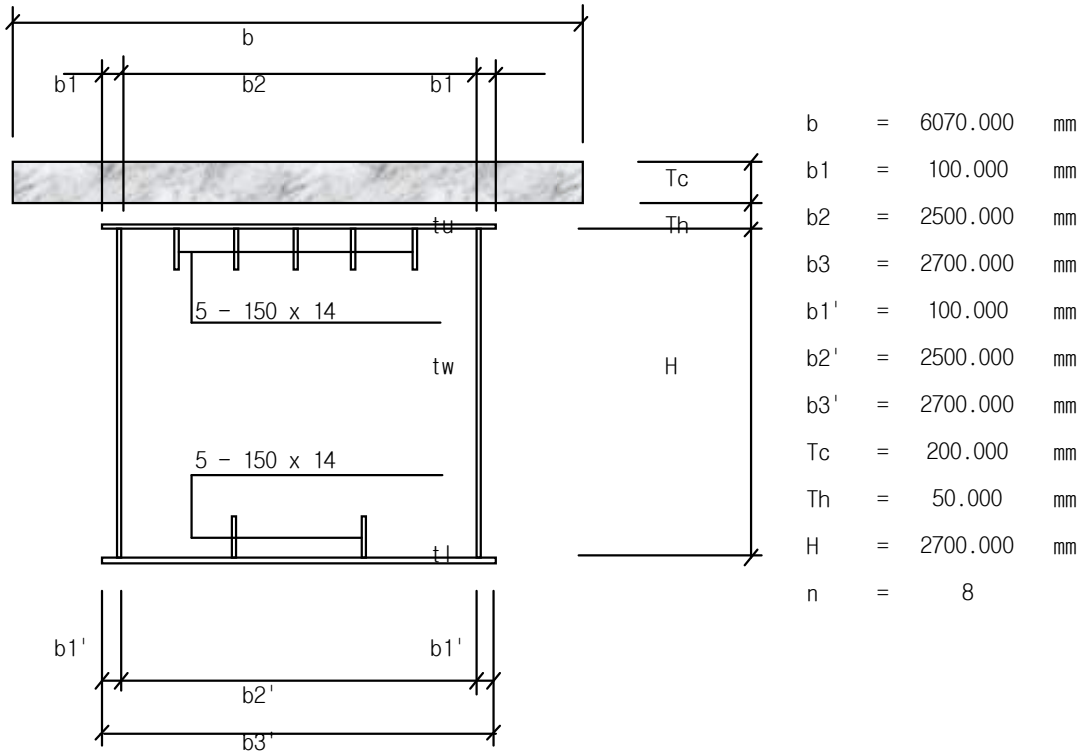
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 156000 + 1214000 / 8 = 307750 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 47.181 + 50.000 + 200.000 / 2 = 1547.18 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1547.181 \times 156000 / 307750 = 784.27 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1547.181 - 784.274 = 762.91 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 202379064902 + 4046666667 / 8 + 156000 \times 762.907^2 \\
&\quad + 1214000 / 8 \times 784.274^2 = 387020325496 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 144871610400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 610806074983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 200.000 / 8 = 37.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2713^2) / (2 \times 2713/12 + 2512/37 + 2512/14) \\
&= 265594526573 \text{ mm}^4
\end{aligned}$$

- Section G1-8



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	1355.00	36585000	49572675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1357.00	-51294600	69606772200	617400
TOTAL		150600		-14709600	153317572200	39406217400

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

$$= 153317572200 + 39406217400 = 192723789600 \text{ mm}^4$$

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

$$= -14709600 / 150600 = -97.67 \text{ mm}$$

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

$$= 192723789600 - 150600 \times (-97.67)^2 = 191287054327 \text{ mm}^4$$

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

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

$$= 141591110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 14.000 / 2 = 2712.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2712^2) / (2 \times 2712/12 + 2512/10 + 2512/14) \\
&= 210329723076 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

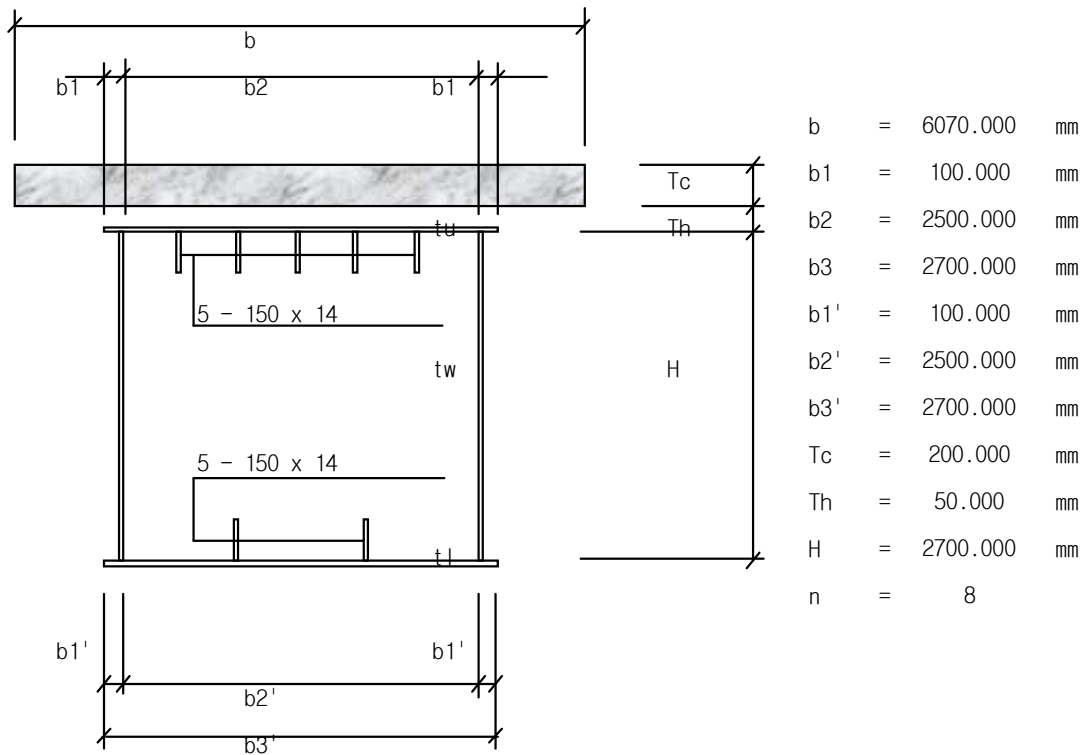
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c / N \\
&= 150600 + 1214000 / 8 = 302350 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 97.673 + 50.000 + 200.000 / 2 = 1597.67 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1597.673 \times 150600 / 302350 = 795.80 \text{ mm} \\
dvs &= dv - dvc = 1597.673 - 795.798 = 801.88 \text{ mm} \\
I_{v33} &= I_{33} + I_c / N + \sum A_s \cdot dvs^2 + A_c / N \cdot dvc^2 \\
&= 191287054327 + 4046666667 / 8 + 150600 \times 801.875^2 \\
&\quad + 1214000 / 8 \times 795.798^2 = 384731725026 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 141591110400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 607525574983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2712^2) / (2 \times 2712/12 + 2512/35 + 2512/14) \\
&= 263997472992 \text{ mm}^4
\end{aligned}$$

- Section G1-9



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 10.0	27000	1355.00	36585000	49572675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1356.00	-43934400	59575046400	388800
TOTAL		145200		-7349400	143285846400	39405988800

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

$$= 143285846400 + 39405988800 = 182691835200 \text{ mm}^4$$

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

$$= -7349400 / 145200 = -50.62 \text{ mm}$$

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

$$= 182691835200 - 145200 \times (-50.616)^2 = 182319840156 \text{ mm}^4$$

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

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

$$= 138310610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 12.000 / 2 = 2711.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/10 + 2512/12) \\
&= 203324113146 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

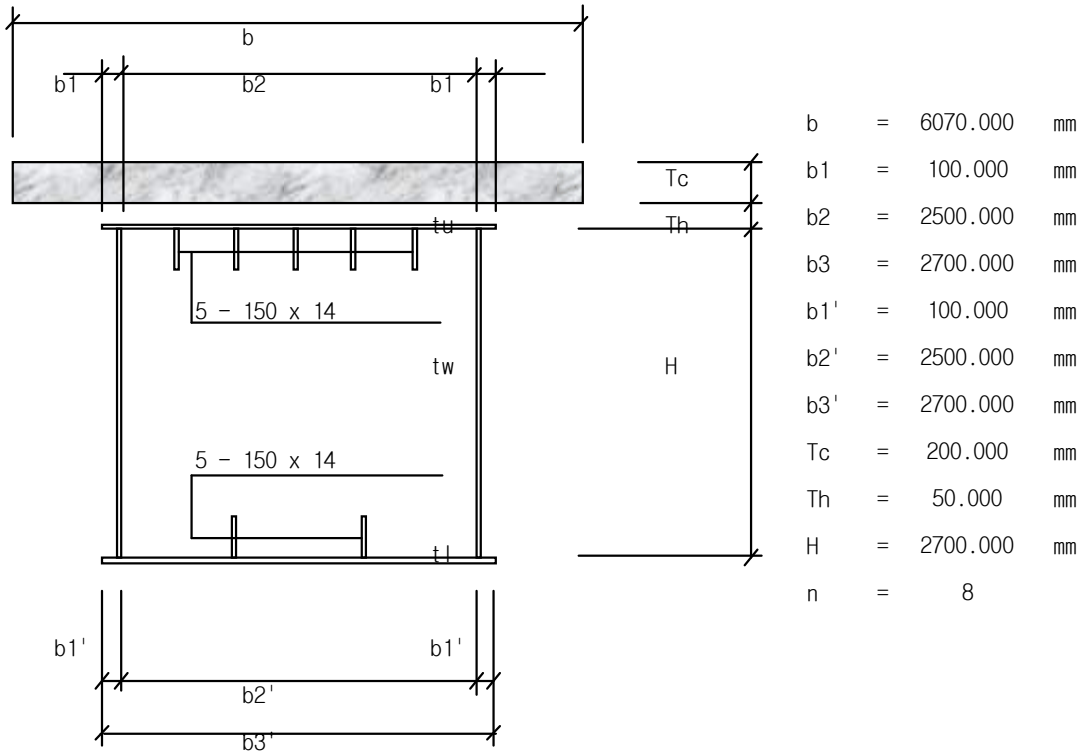
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 145200 + 1214000 / 8 = 296950 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 50.616 + 50.000 + 200.000 / 2 = 1550.62 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1550.616 \times 145200 / 296950 = 758.21 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1550.616 - 758.206 = 792.41 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 182319840156 + 4046666667 / 8 + 145200 \times 792.409^2 \\
&\quad + 1214000 / 8 \times 758.206^2 = 361236145279 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 138310610400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 604245074983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/35 + 2512/12) \\
&= 253099333449 \text{ mm}^4
\end{aligned}$$

- 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 20.0	54000	1360.00	73440000	99878400000	1800000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1356.00	-43934400	59575046400	388800
TOTAL		172200		29505600	193591571400	39407563800

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

$$= 193591571400 + 39407563800 = 232999135200 \text{ mm}^4$$

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

$$= 29505600 / 172200 = 171.34 \text{ mm}$$

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

$$= 232999135200 - 172200 \times 171.34^2 = 227943499710 \text{ mm}^4$$

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

$$= (2700^3 \times 20 / 12) + (2700^3 \times 12 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 154713110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 20.000 / 2 + 12.000 / 2 = 2716.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/20 + 2512/12) \\
&= 236403055350 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

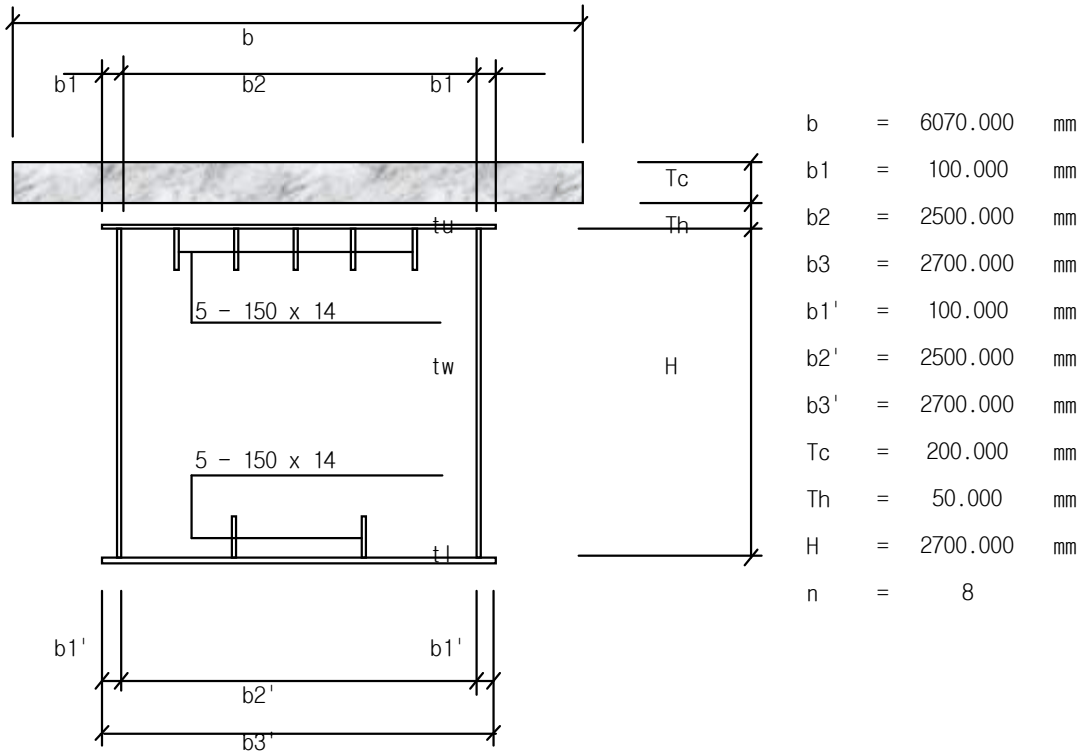
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 172200 + 1214000 / 8 = 323950 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 171.345 + 50.000 + 200.000 / 2 = 1328.66 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1328.655 \times 172200 / 323950 = 706.26 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1328.655 - 706.265 = 622.39 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 227943499710 + 4046666667 / 8 + 172200 \times 622.391^2 \\
&\quad + 1214000 / 8 \times 706.265^2 = 370848795262 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 154713110400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 620647574983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 20.000 + 200.000 / 8 = 45.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/45 + 2512/12) \\
&= 259383229760 \text{ mm}^4
\end{aligned}$$

- Section G1-11



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 20.0	54000	1360.00	73440000	99878400000	1800000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1361.00	-80843400	110027867400	2395800
TOTAL		199200		-7403400	244044392400	39409570800

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

$$= 244044392400 + 39409570800 = 283453963200 \text{ mm}^4$$

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

$$= -7403400 / 199200 = -37.17 \text{ mm}$$

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

$$= 283453963200 - 199200 \times (-37.166)^2 = 283178810933 \text{ mm}^4$$

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

$$= (2700^3 \times 20 / 12) + (2700^3 \times 22 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 171115610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 20.000 / 2 + 22.000 / 2 = 2721.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2721^2) / (2 \times 2721/12 + 2512/20 + 2512/22) \\
&= 269554467680 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

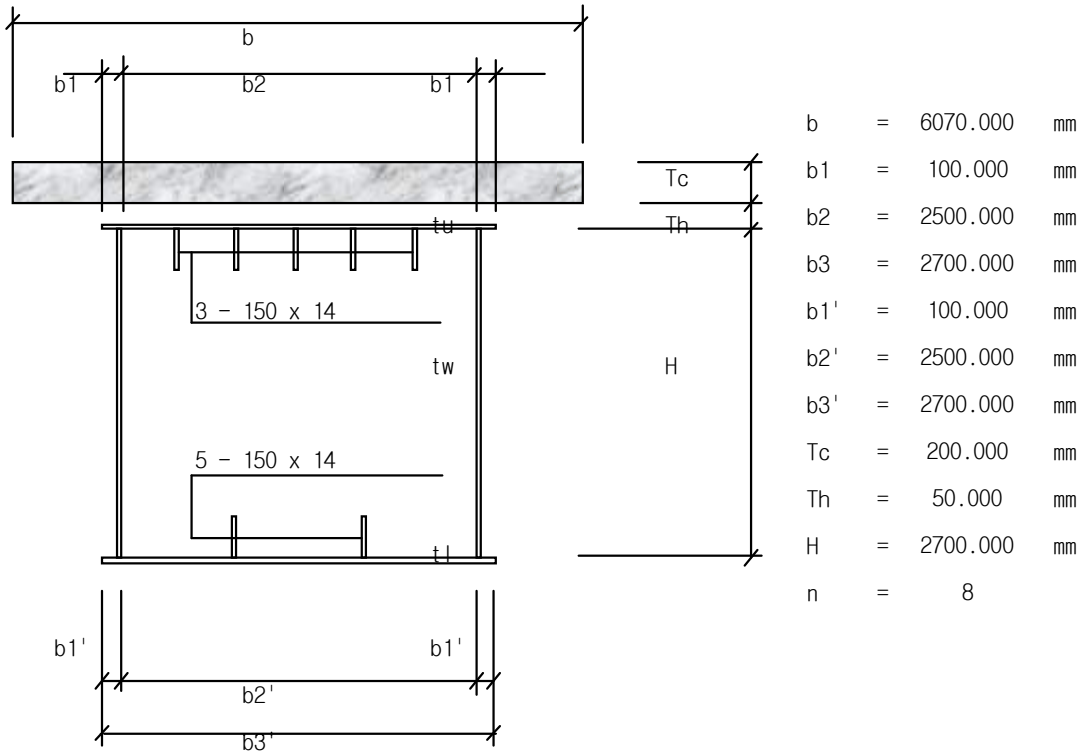
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 199200 + 1214000 / 8 = 350950 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 37.166 + 50.000 + 200.000 / 2 = 1537.17 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1537.166 \times 199200 / 350950 = 872.50 \text{ mm} \\
dvs &= dv - dvc = 1537.166 - 872.499 = 664.67 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 283178810933 + 4046666667 / 8 + 199200 \times 664.667^2 \\
&\quad + 1214000 / 8 \times 872.499^2 = 487207944470 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 171115610400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 637050074983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 20.000 + 200.000 / 8 = 45.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2721^2) / (2 \times 2721/12 + 2512/45 + 2512/22) \\
&= 299720930968 \text{ mm}^4
\end{aligned}$$

- 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 20.0	54000	1360.00	73440000	99878400000	1800000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1361.00	-80843400	110027867400	2395800
TOTAL		195000		-12758400	237216767400	39401695800

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

$$= 237216767400 + 39401695800 = 276618463200 \text{ mm}^4$$

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

$$= -12758400 / 195000 = -65.43 \text{ mm}$$

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

$$= 276618463200 - 195000 \times (-65.428)^2 = 275783710530 \text{ mm}^4$$

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

$$= (2700^3 \times 20 / 12) + (2700^3 \times 22 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 171115610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 20.000 / 2 + 22.000 / 2 = 2721.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2721^2) / (2 \times 2721/12 + 2512/20 + 2512/22) \\
&= 269554467680 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

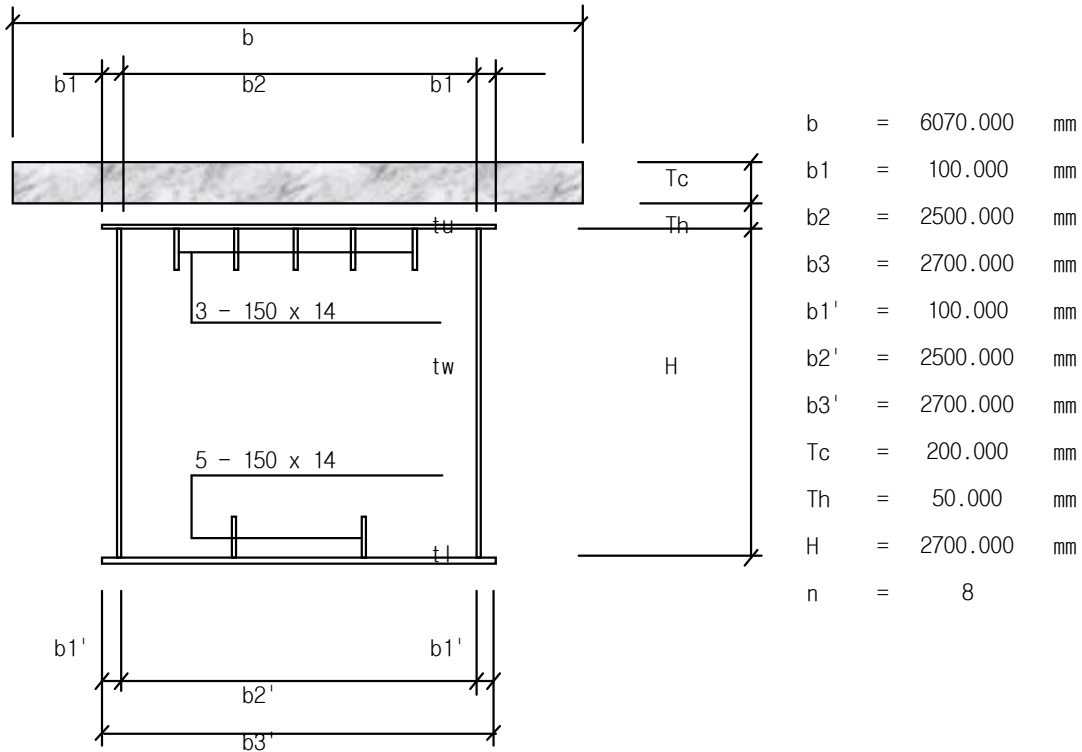
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c / N \\
&= 195000 + 1214000 / 8 = 346750 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 65.428 + 50.000 + 200.000 / 2 = 1565.43 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1565.428 \times 195000 / 346750 = 880.34 \text{ mm} \\
dvs &= dv - dvc = 1565.428 - 880.341 = 685.09 \text{ mm} \\
I_{v33} &= I_{33} + I_c / N + \sum A_s \cdot dvs^2 + A_c / N \cdot dvc^2 \\
&= 275783710530 + 4046666667 / 8 + 195000 \times 685.086^2 \\
&\quad + 1214000 / 8 \times 880.341^2 = 485417872105 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 171115610400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 637050074983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 20.000 + 200.000 / 8 = 45.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2721^2) / (2 \times 2721/12 + 2512/45 + 2512/22) \\
&= 299720930968 \text{ mm}^4
\end{aligned}$$

- 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 30.0	81000	1365.00	110565000	150921225000	6075000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1361.00	-80843400	110027867400	2395800
TOTAL		222000		24366600	288259592400	39405970800

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

$$= 288259592400 + 39405970800 = 327665563200 \text{ mm}^4$$

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

$$= 24366600 / 222000 = 109.76 \text{ mm}$$

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

$$= 327665563200 - 222000 \times 109.759^2 = 324991098355 \text{ mm}^4$$

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

$$= (2700^3 \times 30 / 12) + (2700^3 \times 22 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 187518110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 30.000 / 2 + 22.000 / 2 = 2726.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2726^2) / (2 \times 2726/12 + 2512/30 + 2512/22) \\
&= 287566231117 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

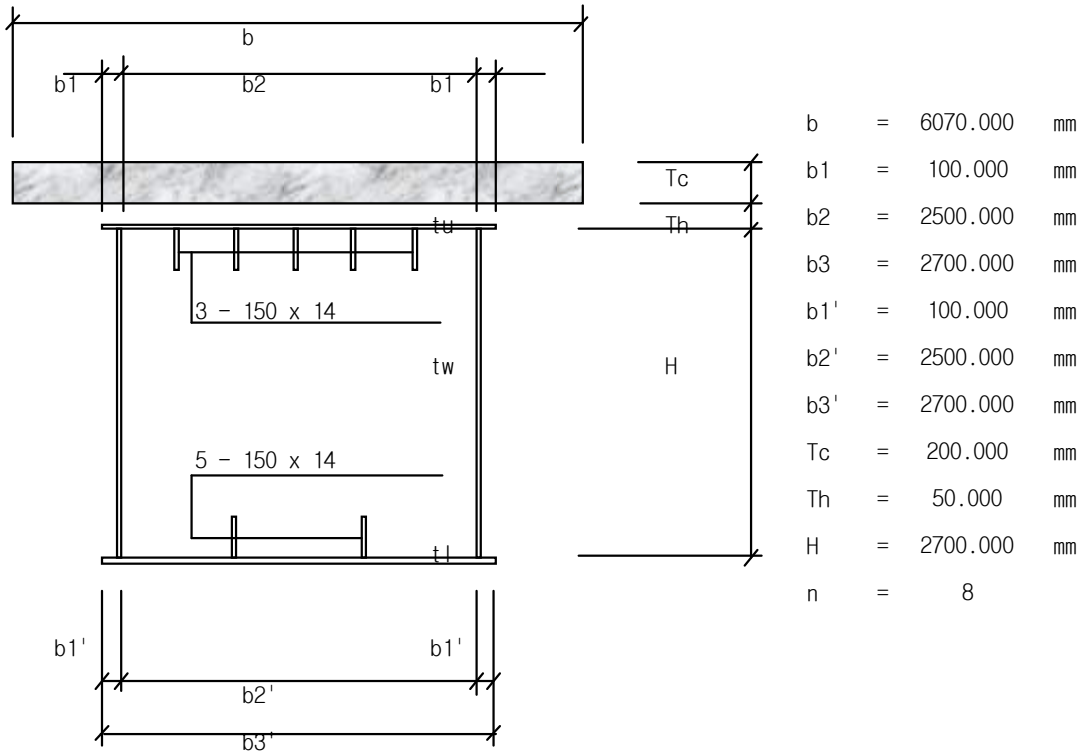
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 222000 + 1214000 / 8 = 373750 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 109.759 + 50.000 + 200.000 / 2 = 1390.24 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1390.241 \times 222000 / 373750 = 825.77 \text{ mm} \\
dvs &= dv - dvc = 1390.241 - 825.775 = 564.47 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 324991098355 + 4046666667 / 8 + 222000 \times 564.466^2 \\
&\quad + 1214000 / 8 \times 825.775^2 = 499709855809 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 187518110400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 653452574983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 30.000 + 200.000 / 8 = 55.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2726^2) / (2 \times 2726/12 + 2512/55 + 2512/22) \\
&= 305386421676 \text{ mm}^4
\end{aligned}$$

- 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 30.0	81000	1365.00	110565000	150921225000	6075000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 32.0	86400	-1366.00	-118022400	161218598400	7372800
TOTAL		249000		-12812400	339450323400	39410947800

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

$$= 339450323400 + 39410947800 = 378861271200 \text{ mm}^4$$

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

$$= -12812400 / 249000 = -51.46 \text{ mm}$$

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

$$= 378861271200 - 249000 \times (-51.455)^2 = 378202003755 \text{ mm}^4$$

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

$$= (2700^3 \times 30 / 12) + (2700^3 \times 32 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 203920610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 30.000 / 2 + 32.000 / 2 = 2731.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2731^2) / (2 \times 2731/12 + 2512/30 + 2512/32) \\
&= 304913067146 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

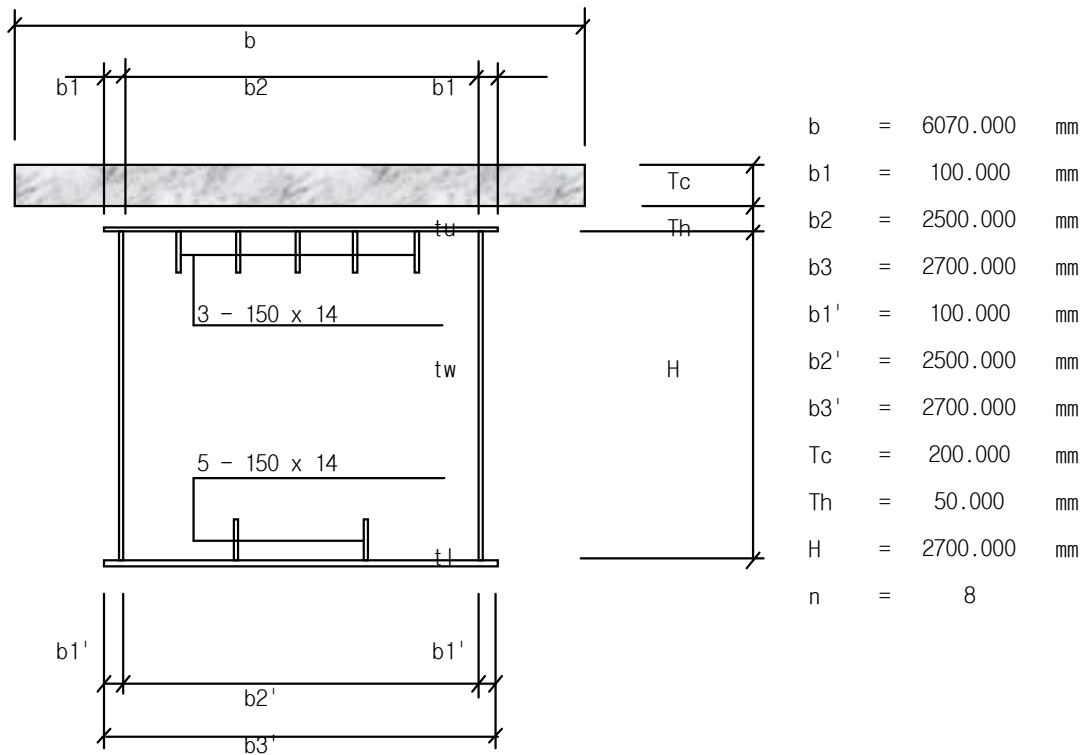
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c / N \\
&= 249000 + 1214000 / 8 = 400750 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 51.455 + 50.000 + 200.000 / 2 = 1551.46 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1551.455 \times 249000 / 400750 = 963.97 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1551.455 - 963.974 = 587.48 \text{ mm} \\
I_{v33} &= I_{33} + I_c / N + \sum A_s \cdot d_{vs}^2 + A_c / N \cdot d_{vc}^2 \\
&= 378202003755 + 4046666667 / 8 + 249000 \times 587.482^2 \\
&\quad + 1214000 / 8 \times 963.974^2 = 605659369053 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 203920610400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 669855074983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 30.000 + 200.000 / 8 = 55.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2731^2) / (2 \times 2731/12 + 2512/55 + 2512/32) \\
&= 324944807181 \text{ mm}^4
\end{aligned}$$

- Section G1-15



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 20.0	54000	1360.00	73440000	99878400000	1800000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 32.0	86400	-1366.00	-118022400	161218598400	7372800
TOTAL		222000		-49937400	288407498400	39406672800

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

$$= 288407498400 + 39406672800 = 327814171200 \text{ mm}^4$$

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

$$= -49937400 / 222000 = -224.94 \text{ mm}$$

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

$$= 327814171200 - 222000 \times (-224.94)^2 = 316581090485 \text{ mm}^4$$

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

$$= (2700^3 \times 20 / 12) + (2700^3 \times 32 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 187518110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 20.000 / 2 + 32.000 / 2 = 2726.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2726^2) / (2 \times 2726/12 + 2512/20 + 2512/32) \\
&= 284865041067 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

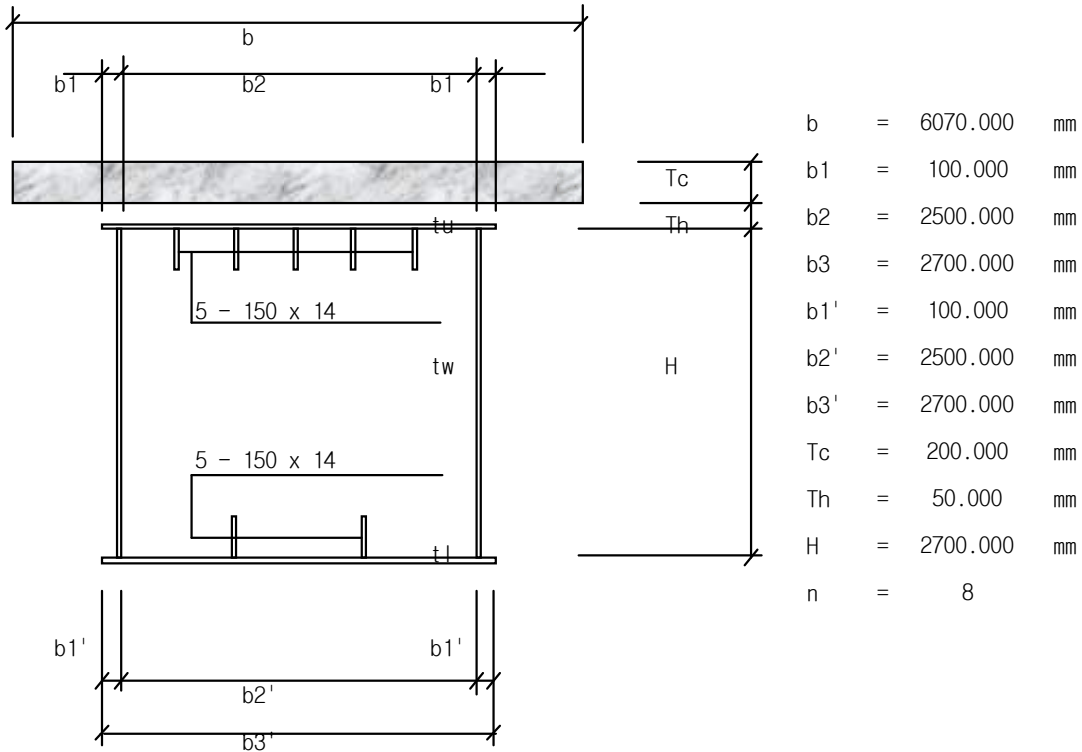
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 222000 + 1214000 / 8 = 373750 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - -224.943 + 50.000 + 200.000 / 2 = 1724.94 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1724.943 \times 222000 / 373750 = 1024.58 \text{ mm} \\
dvs &= dv - dvc = 1724.943 - 1024.582 = 700.36 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 316581090485 + 4046666667 / 8 + 222000 \times 700.362^2 \\
&\quad + 1214000 / 8 \times 1024.582^2 = 585281562878 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 187518110400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 653452574983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 20.000 + 200.000 / 8 = 45.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2726^2) / (2 \times 2726/12 + 2512/45 + 2512/32) \\
&= 318632240484 \text{ mm}^4
\end{aligned}$$

- 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 10.0	27000	1355.00	36585000	49572675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1361.00	-80843400	110027867400	2395800
TOTAL		172200		-44258400	193738667400	39407995800

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

$$= 193738667400 + 39407995800 = 233146663200 \text{ mm}^4$$

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

$$= -44258400 / 172200 = -257.02 \text{ mm}$$

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

$$= 233146663200 - 172200 \times (-257.017)^2 = 221771483348 \text{ mm}^4$$

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

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

$$= 154713110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 22.000 / 2 = 2716.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/10 + 2512/22) \\
&= 227603925491 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

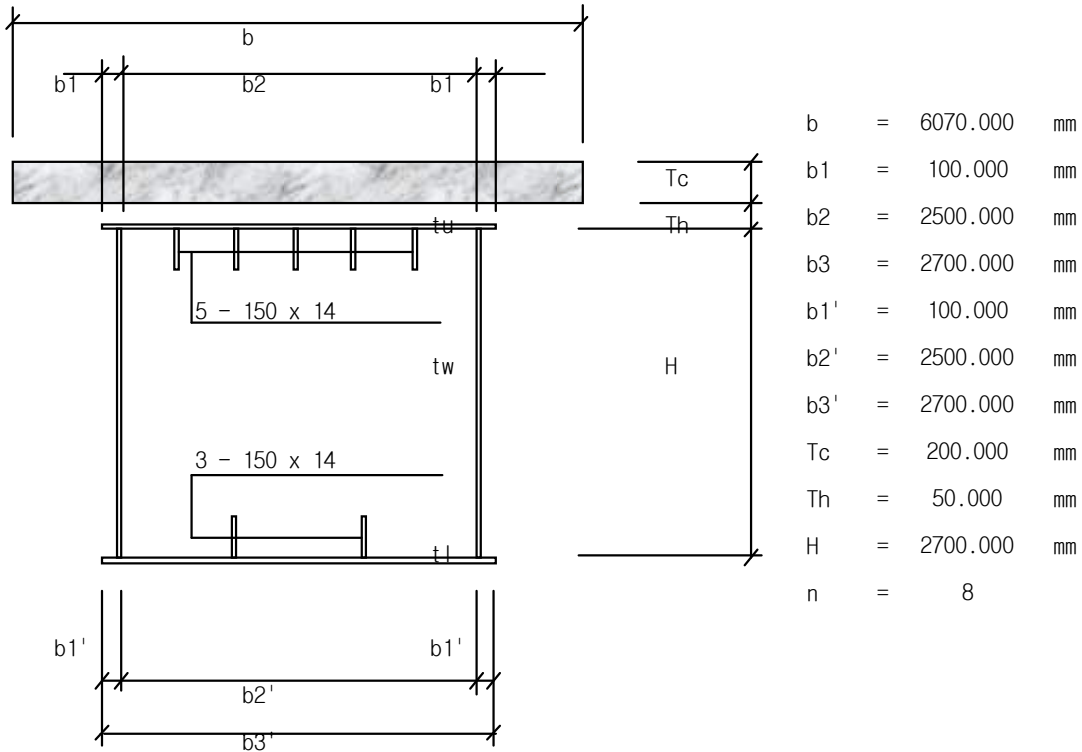
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 172200 + 1214000 / 8 = 323950 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - -257.017 + 50.000 + 200.000 / 2 = 1757.02 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1757.017 \times 172200 / 323950 = 933.97 \text{ mm} \\
dvs &= dv - dvc = 1757.017 - 933.966 = 823.05 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 221771483348 + 4046666667 / 8 + 172200 \times 823.051^2 \\
&\quad + 1214000 / 8 \times 933.966^2 = 471298331167 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 154713110400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 620647574983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/35 + 2512/22) \\
&= 291552208882 \text{ mm}^4
\end{aligned}$$

- 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 10.0	27000	1355.00	36585000	49572675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1356.00	-43934400	59575046400	388800
TOTAL		141000		-1994400	136458221400	39398113800

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

$$= 136458221400 + 39398113800 = 175856335200 \text{ mm}^4$$

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

$$= -1994400 / 141000 = -14.14 \text{ mm}$$

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

$$= 175856335200 - 141000 \times (-14.14)^2 = 175828125049 \text{ mm}^4$$

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

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

$$= 138310610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 12.000 / 2 = 2711.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/10 + 2512/12) \\
&= 203324113146 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

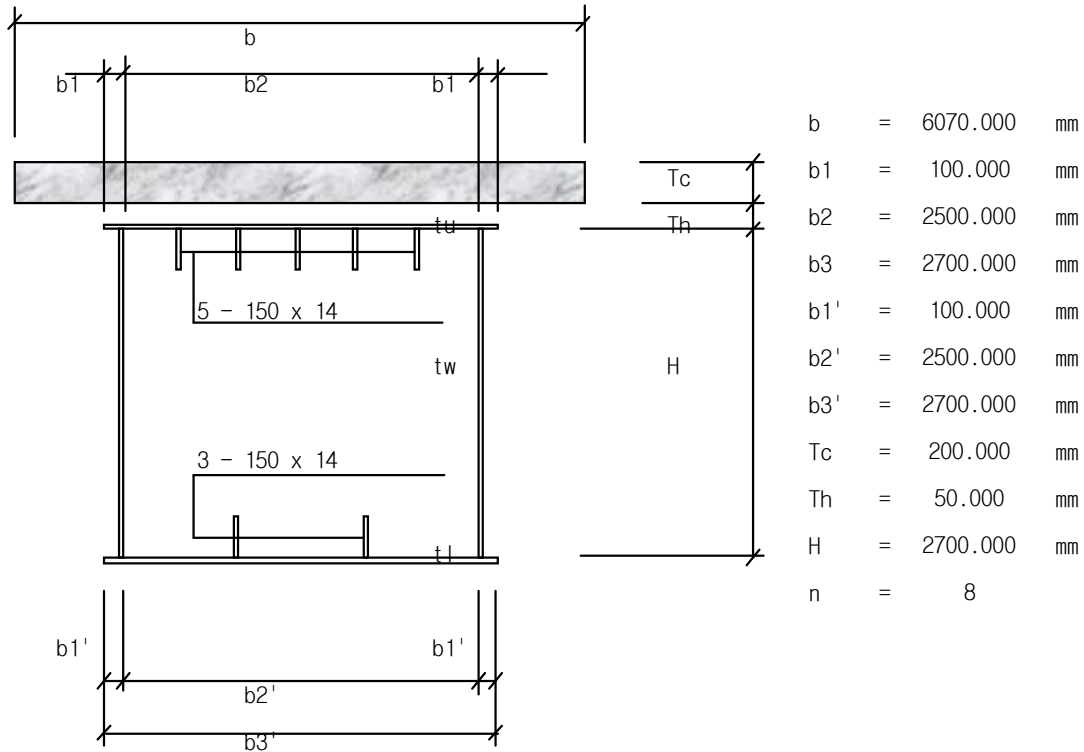
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 141000 + 1214000 / 8 = 292750 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 14.145 + 50.000 + 200.000 / 2 = 1514.14 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1514.145 \times 141000 / 292750 = 729.27 \text{ mm} \\
dvs &= dv - dvc = 1514.145 - 729.272 = 784.87 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 175828125049 + 4046666667 / 8 + 141000 \times 784.873^2 \\
&\quad + 1214000 / 8 \times 729.272^2 = 343899864413 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 138310610400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 604245074983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/35 + 2512/12) \\
&= 253099333449 \text{ mm}^4
\end{aligned}$$

- 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 12.0	32400	1356.00	43934400	59575046400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1356.00	-43934400	59575046400	388800
TOTAL		146400		5355000	146460592800	39398277600

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

$$= 146460592800 + 39398277600 = 185858870400 \text{ mm}^4$$

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

$$= 5355000 / 146400 = 36.58 \text{ mm}$$

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

$$= 185858870400 - 146400 \times 36.58^2 = 185662995912 \text{ mm}^4$$

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

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

$$= 141591110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 12.000 / 2 + 12.000 / 2 = 2712.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2712^2) / (2 \times 2712/12 + 2512/12 + 2512/12) \\
&= 213219398554 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

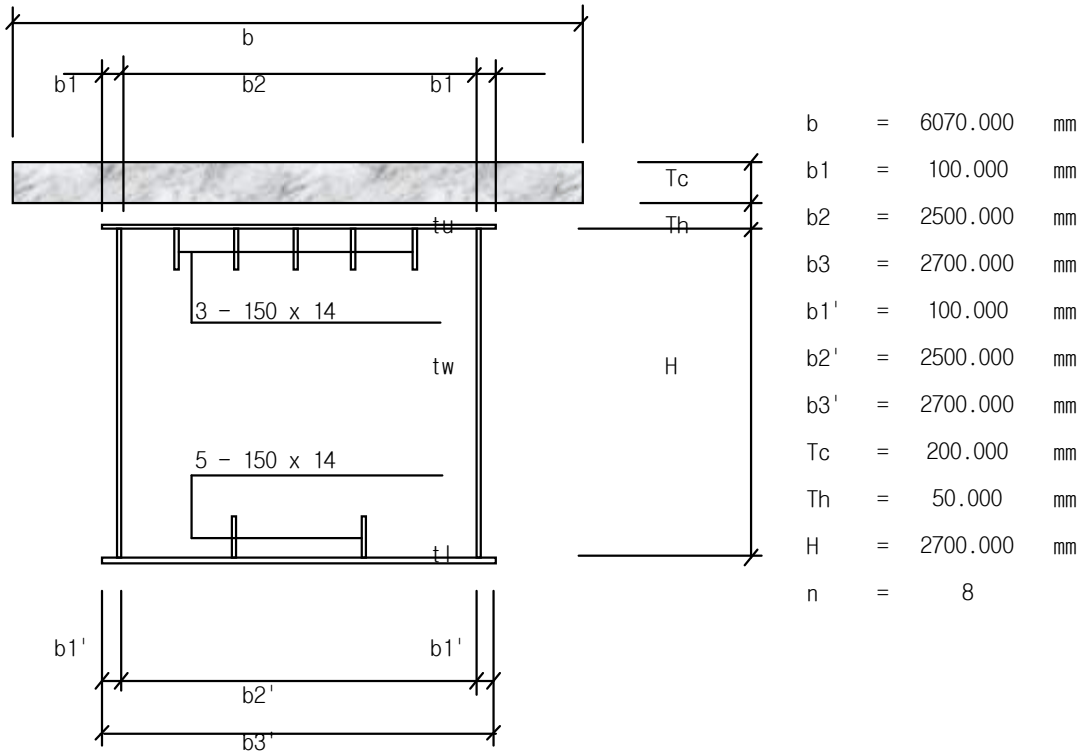
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 146400 + 1214000 / 8 = 298150 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 36.578 + 50.000 + 200.000 / 2 = 1463.42 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1463.422 \times 146400 / 298150 = 718.58 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1463.422 - 718.581 = 744.84 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 185662995912 + 4046666667 / 8 + 146400 \times 744.841^2 \\
&\quad + 1214000 / 8 \times 718.581^2 = 345747263603 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 141591110400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 607525574983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 200.000 / 8 = 37.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2712^2) / (2 \times 2712/12 + 2512/37 + 2512/12) \\
&= 254575701150 \text{ mm}^4
\end{aligned}$$

- 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	1355.00	36585000	49572675000	225000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1356.00	-43934400	59575046400	388800
TOTAL		141000		-12704400	136458221400	39398113800

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

$$= 136458221400 + 39398113800 = 175856335200 \text{ mm}^4$$

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

$$= -12704400 / 141000 = -90.10 \text{ mm}$$

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

$$= 175856335200 - 141000 \times (-90.10)^2 = 174711641729 \text{ mm}^4$$

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

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

$$= 138310610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 12.000 / 2 = 2711.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/10 + 2512/12) \\
&= 203324113146 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

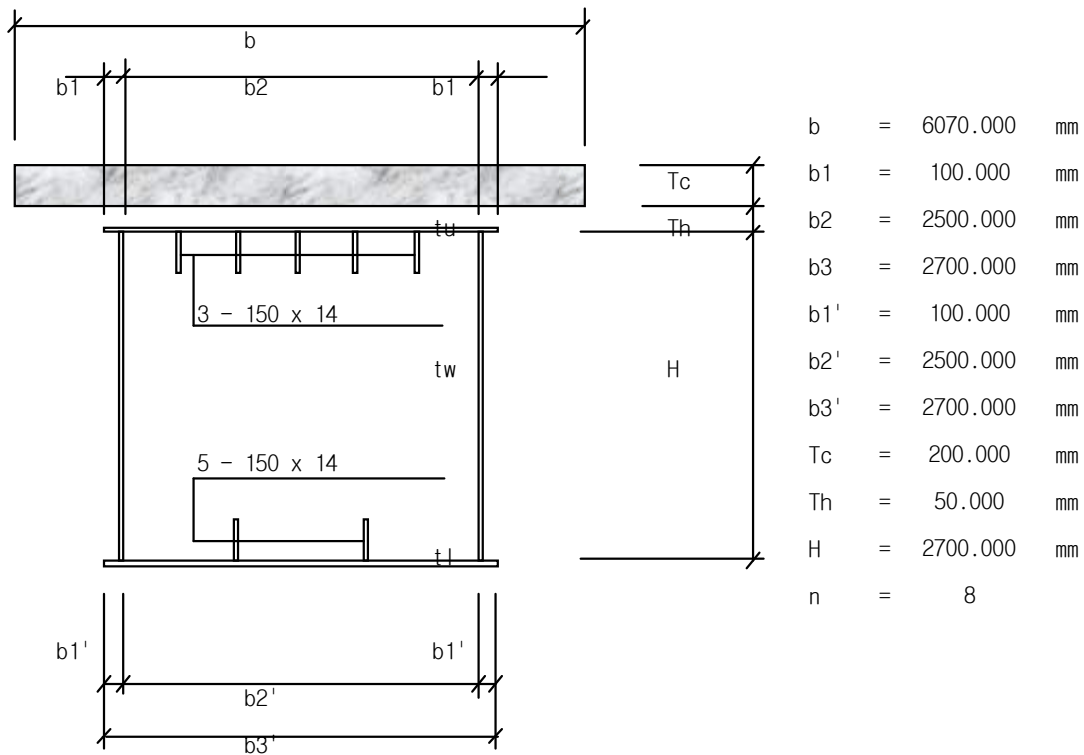
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c / N \\
&= 141000 + 1214000 / 8 = 292750 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 90.102 + 50.000 + 200.000 / 2 = 1590.10 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1590.102 \times 141000 / 292750 = 765.86 \text{ mm} \\
dvs &= dv - dvc = 1590.102 - 765.856 = 824.25 \text{ mm} \\
I_{v33} &= I_{33} + I_c / N + \sum A_s \cdot dvs^2 + A_c / N \cdot dvc^2 \\
&= 174711641729 + 4046666667 / 8 + 141000 \times 824.246^2 \\
&\quad + 1214000 / 8 \times 765.856^2 = 360017040679 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 138310610400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 604245074983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/35 + 2512/12) \\
&= 253099333449 \text{ mm}^4
\end{aligned}$$

- 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 10.0	27000	1355.00	36585000	49572675000	225000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1361.00	-80843400	110027867400	2395800
TOTAL		168000		-49613400	186911042400	39400120800

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

$$= 186911042400 + 39400120800 = 226311163200 \text{ mm}^4$$

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

$$= -49613400 / 168000 = -295.32 \text{ mm}$$

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

$$= 226311163200 - 168000 \times (-295.318)^2 = 211659440226 \text{ mm}^4$$

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

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

$$= 154713110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 22.000 / 2 = 2716.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/10 + 2512/22) \\
&= 227603925491 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

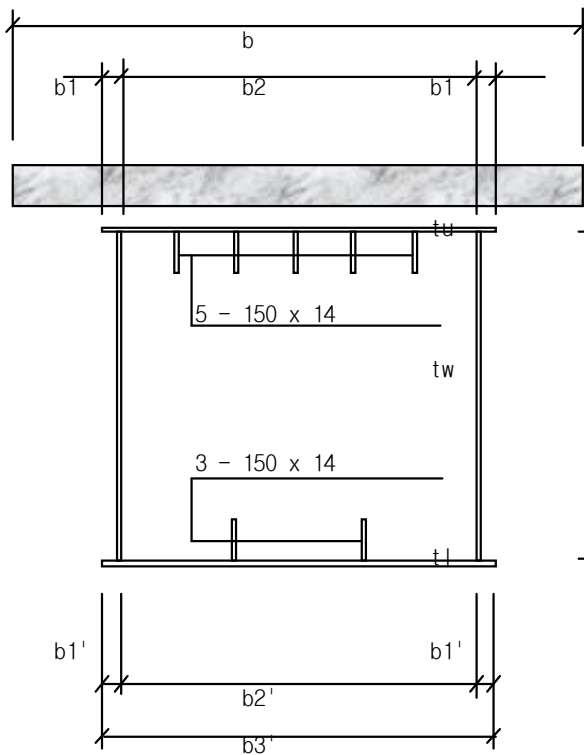
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6070.000 \times 200.000 = 1214000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 168000 + 1214000 / 8 = 319750 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6070.000 \times 200.000^3 / 12 = 4046666667 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - -295.318 + 50.000 + 200.000 / 2 = 1795.32 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1795.318 \times 168000 / 319750 = 943.28 \text{ mm} \\
dvs &= dv - dvc = 1795.318 - 943.279 = 852.04 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 211659440226 + 4046666667 / 8 + 168000 \times 852.039^2 \\
&\quad + 1214000 / 8 \times 943.279^2 = 469151667027 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 154713110400 + 6070.000^3 \\
&\quad \times 200.000 / 12 / 8 = 620647574983 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/35 + 2512/22) \\
&= 291552208882 \text{ mm}^4
\end{aligned}$$

- Section G2-1



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	=	200.000	mm
Th	=	50.000	mm
H	=	2700.000	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	1355.00	36585000	49572675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 10.0	27000	-1355.00	-36585000	49572675000	225000
TOTAL		135600		5355000	126455850000	39397950000

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

$$= 126455850000 + 39397950000 = 165853800000 \text{ mm}^4$$

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

$$= 5355000 / 135600 = 39.49 \text{ mm}$$

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

$$= 165853800000 - 135600 \times 39.491^2 = 165642324889 \text{ mm}^4$$

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

$$= (2700^3 \times 10 / 12) + (2700^3 \times 10 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 135030110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 10.000 / 2 = 2710.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2710^2) / (2 \times 2710/12 + 2512/10 + 2512/10) \\
&= 194293879745 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

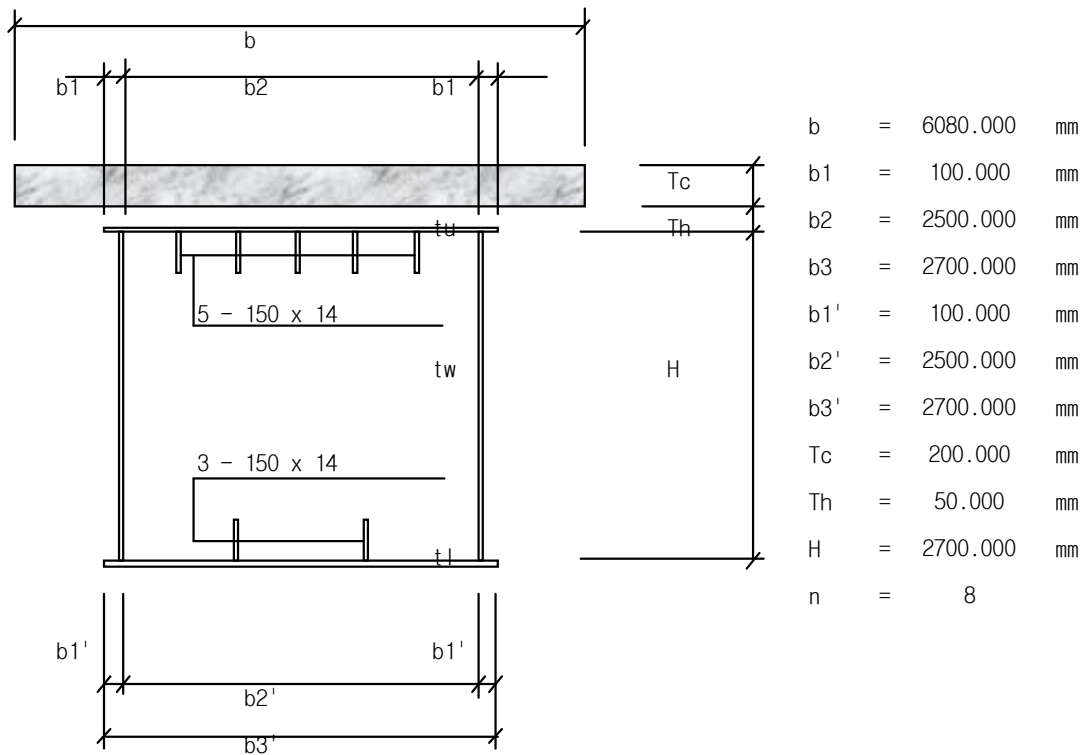
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 135600 + 1216000 / 8 = 287600 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 39.491 + 50.000 + 200.000 / 2 = 1460.51 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1460.509 \times 135600 / 287600 = 688.61 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1460.509 - 688.613 = 771.90 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 165642324889 + 4053333333 / 8 + 135600 \times 771.896^2 \\
&\quad + 1216000 / 8 \times 688.613^2 = 319019173117 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 135030110400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 603271177067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2710^2) / (2 \times 2710/12 + 2512/35 + 2512/10) \\
&= 239297957770 \text{ mm}^4
\end{aligned}$$

- 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	1356.00	43934400	59575046400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 10.0	27000	-1355.00	-36585000	49572675000	225000
TOTAL		141000		12704400	136458221400	39398113800

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

$$= 136458221400 + 39398113800 = 175856335200 \text{ mm}^4$$

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

$$= 12704400 / 141000 = 90.10 \text{ mm}$$

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

$$= 175856335200 - 141000 \times 90.10^2 = 174711641729 \text{ mm}^4$$

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

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

$$= 138310610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 12.000 / 2 + 10.000 / 2 = 2711.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/12 + 2512/10) \\
&= 203324113146 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

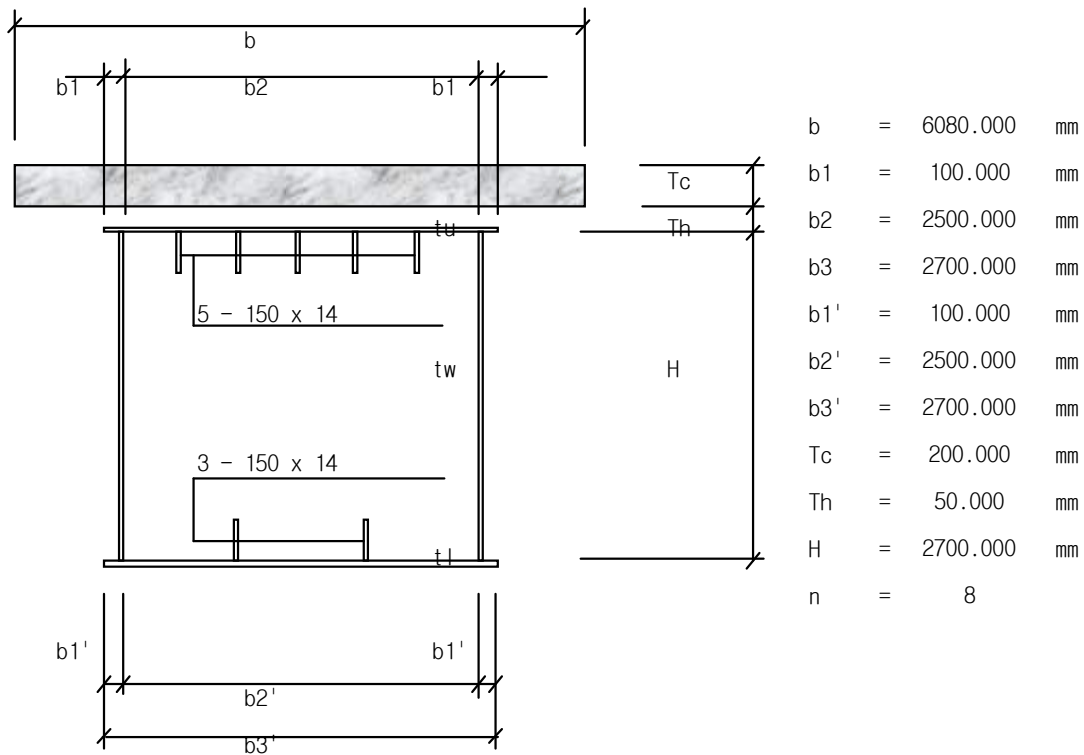
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c / N \\
&= 141000 + 1216000 / 8 = 293000 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 90.102 + 50.000 + 200.000 / 2 = 1409.90 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1409.898 \times 141000 / 293000 = 678.48 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1409.898 - 678.483 = 731.41 \text{ mm} \\
I_{v33} &= I_{33} + I_c / N + \sum A_s \cdot d_{vs}^2 + A_c / N \cdot d_{vc}^2 \\
&= 174711641729 + 4053333333 / 8 + 141000 \times 731.415^2 \\
&\quad + 1216000 / 8 \times 678.483^2 = 320620311835 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 138310610400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 606551677067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 200.000 / 8 = 37.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/37 + 2512/10) \\
&= 240627932897 \text{ mm}^4
\end{aligned}$$

- Section G2-3



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	1356.00	43934400	59575046400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1357.00	-51294600	69606772200	617400
TOTAL		151800		-2005200	156492318600	39398506200

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

$$= 156492318600 + 39398506200 = 195890824800 \text{ mm}^4$$

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

$$= -2005200 / 151800 = -13.21 \text{ mm}$$

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

$$= 195890824800 - 151800 \times (-13.209)^2 = 195864337138 \text{ mm}^4$$

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

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

$$= 144871610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 12.000 / 2 + 14.000 / 2 = 2713.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2713^2) / (2 \times 2713/12 + 2512/12 + 2512/14) \\
&= 220922393940 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

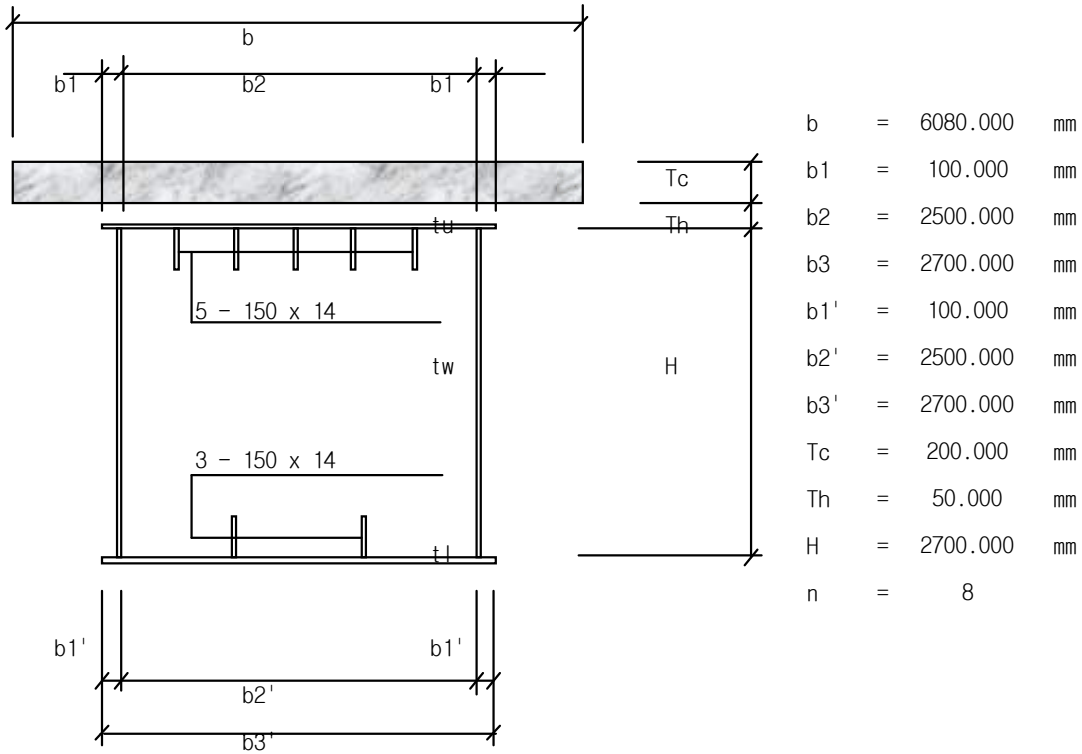
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 151800 + 1216000 / 8 = 303800 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 13.209 + 50.000 + 200.000 / 2 = 1513.21 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1513.209 \times 151800 / 303800 = 756.11 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1513.209 - 756.107 = 757.10 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 195864337138 + 4053333333 / 8 + 151800 \times 757.103^2 \\
&\quad + 1216000 / 8 \times 756.107^2 = 370281462411 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 144871610400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 613112677067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 200.000 / 8 = 37.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2713^2) / (2 \times 2713/12 + 2512/37 + 2512/14) \\
&= 265594526573 \text{ mm}^4
\end{aligned}$$

- Section G2-4



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 16.0	43200	1358.00	58665600	79667884800	921600
UPPER RIB	5	-	150.0	X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2	-	2700.0	X 12.0	64800				39366000000
LOWER RIB	3	-	150.0	X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1	-	2700.0	X 14.0	37800	-1357.00	-51294600	69606772200	617400
TOTAL					162600		12726000	176585157000	39399039000

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

$$= 176585157000 + 39399039000 = 215984196000 \text{ mm}^4$$

$$\delta s = \frac{\sum AsY}{\sum As} = \frac{12726000}{162600} = 78.27 \text{ mm}$$

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

$$= 215984196000 - 162600 \times 78.266^2 = 214988186923 \text{ mm}^4$$

$$\begin{aligned}
 I_{22} &= (b_3^3 \times t_u / 12) + (b_3^{13} \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2 \\
 &= (2700^3 \times 16 / 12) + (2700^3 \times 14 / 12) + ((2700 \times 12^3 / 12) \\
 &\quad + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 151432610400 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 16.000 / 2 + 14.000 / 2 = 2715.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2715^2) / (2 \times 2715/12 + 2512/16 + 2512/14) \\
&= 235831191268 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

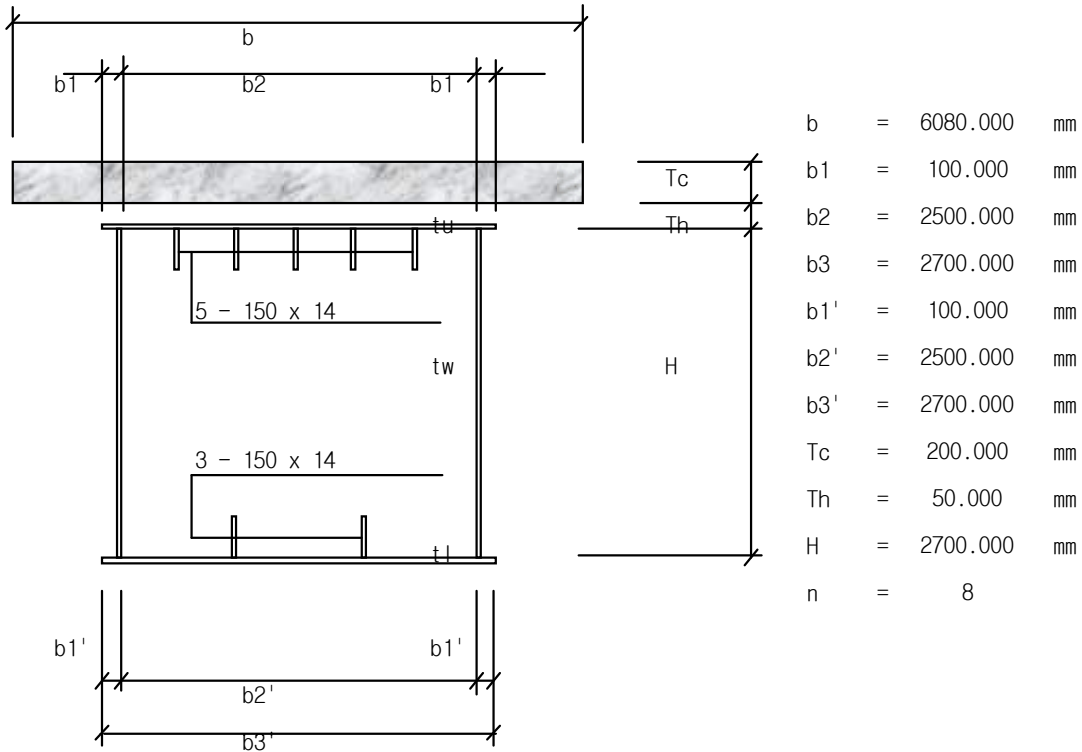
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 162600 + 1216000 / 8 = 314600 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 78.266 + 50.000 + 200.000 / 2 = 1421.73 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1421.734 \times 162600 / 314600 = 734.82 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1421.734 - 734.819 = 686.92 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 214988186923 + 4053333333 / 8 + 162600 \times 686.915^2 \\
&\quad + 1216000 / 8 \times 734.819^2 = 374291857339 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 151432610400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 619673677067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 16.000 + 200.000 / 8 = 41.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2715^2) / (2 \times 2715/12 + 2512/41 + 2512/14) \\
&= 268399893967 \text{ mm}^4
\end{aligned}$$

- 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	1358.00	58665600	79667884800	921600
UPPER RIB	5	-	150.0	X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2	-	2700.0	X 12.0	64800				39366000000
LOWER RIB	3	-	150.0	X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1	-	2700.0	X 20.0	54000	-1360.00	-73440000	99878400000	1800000
TOTAL					178800		-9419400	206856784800	39400221600

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

$$= 206856784800 + 39400221600 = 246257006400 \text{ mm}^4$$

$$\delta s = \frac{\sum AsY}{\sum As} = \frac{-9419400}{178800} = -52.68 \text{ mm}$$

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

$$= 246257006400 - 178800 \times (-52.681)^2 = 245760781029 \text{ mm}^4$$

$$\begin{aligned}
 I_{22} &= (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2 \\
 &= (2700^3 \times 16 / 12) + (2700^3 \times 20 / 12) + ((2700 \times 12^3 / 12) \\
 &\quad + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 161274110400 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 16.000 / 2 + 20.000 / 2 = 2718.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2718^2) / (2 \times 2718/12 + 2512/16 + 2512/20) \\
&= 253487440149 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

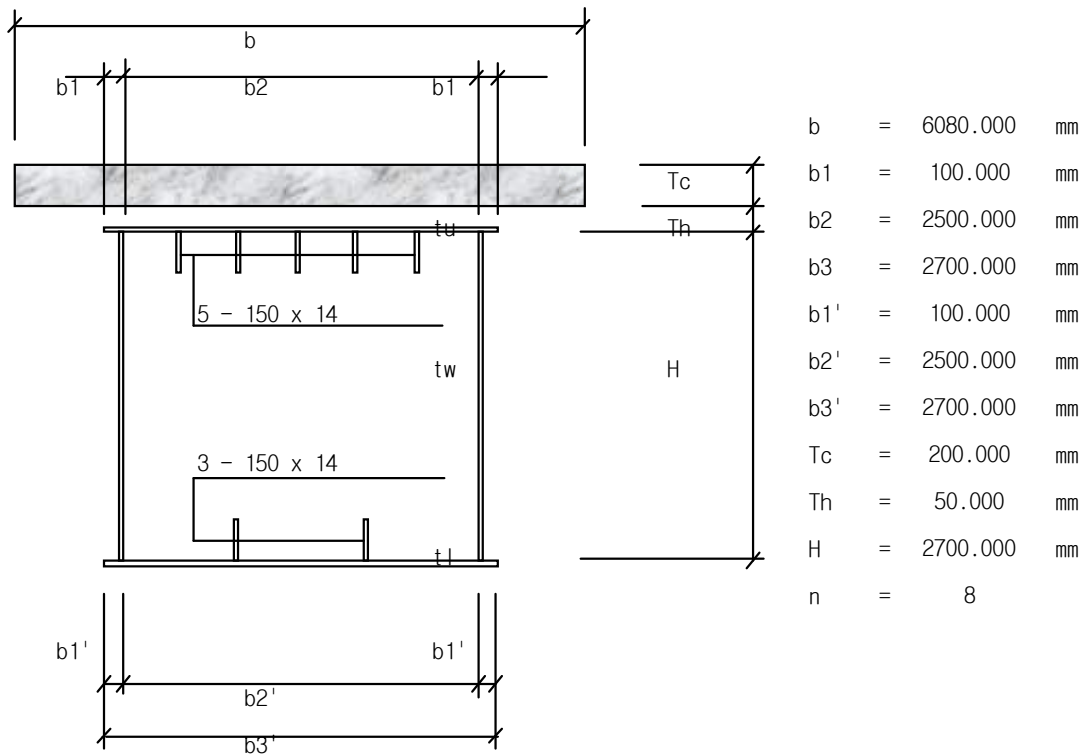
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 178800 + 1216000 / 8 = 330800 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 52.681 + 50.000 + 200.000 / 2 = 1552.68 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1552.681 \times 178800 / 330800 = 839.24 \text{ mm} \\
dvs &= dv - dvc = 1552.681 - 839.236 = 713.44 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 245760781029 + 4053333333 / 8 + 178800 \times 713.445^2 \\
&\quad + 1216000 / 8 \times 839.236^2 = 444333568180 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 161274110400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 629515177067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 16.000 + 200.000 / 8 = 41.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2718^2) / (2 \times 2718/12 + 2512/41 + 2512/20) \\
&= 291412096999 \text{ mm}^4
\end{aligned}$$

- Section G2-6



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 12.0	32400	1356.00	43934400	59575046400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 20.0	54000	-1360.00	-73440000	99878400000	1800000
TOTAL		168000		-24150600	186763946400	39399688800

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

$$= 186763946400 + 39399688800 = 226163635200 \text{ mm}^4$$

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

$$= -24150600 / 168000 = -143.75 \text{ mm}$$

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

$$= 226163635200 - 168000 \times (-143.75)^2 = 222691900198 \text{ mm}^4$$

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

$$= (2700^3 \times 12 / 12) + (2700^3 \times 20 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 154713110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 12.000 / 2 + 20.000 / 2 = 2716.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/12 + 2512/20) \\
&= 236403055350 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

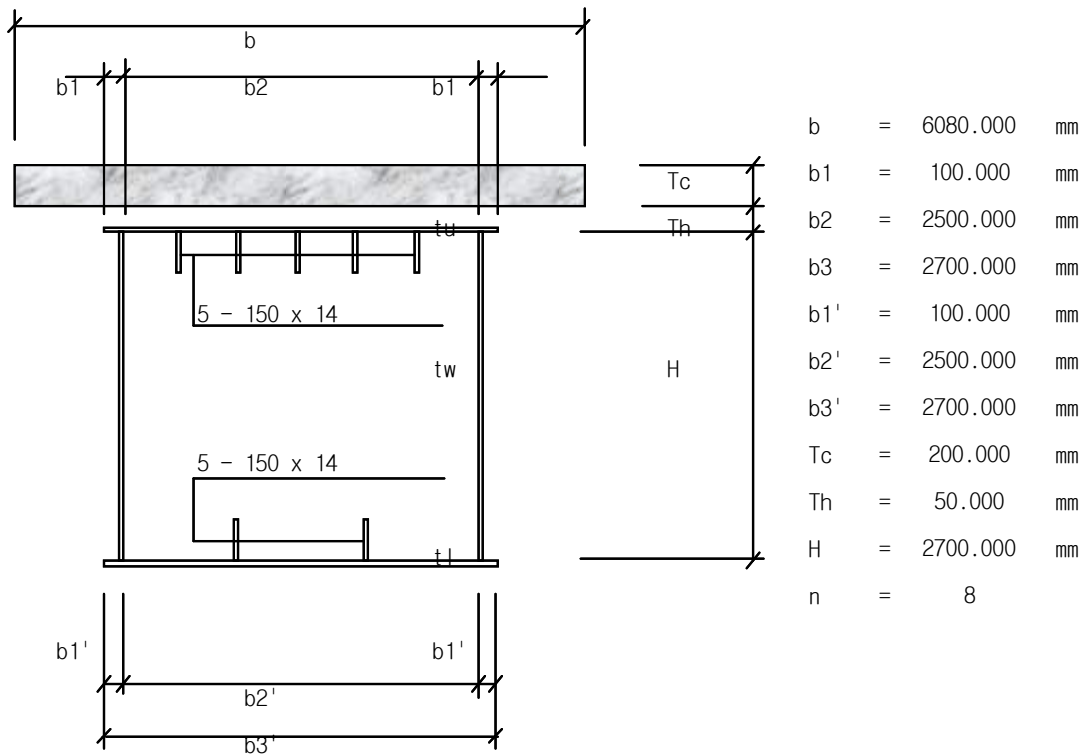
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 168000 + 1216000 / 8 = 320000 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 143.754 + 50.000 + 200.000 / 2 = 1643.75 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1643.754 \times 168000 / 320000 = 862.97 \text{ mm} \\
dvs &= dv - dvc = 1643.754 - 862.971 = 780.78 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 222691900198 + 4053333333 / 8 + 168000 \times 780.783^2 \\
&\quad + 1216000 / 8 \times 862.971^2 = 438812245991 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 154713110400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 622954177067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 200.000 / 8 = 37.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/37 + 2512/20) \\
&= 288150708410 \text{ mm}^4
\end{aligned}$$

- 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 12.0	32400	1356.00	43934400	59575046400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1357.00	-51294600	69606772200	617400
TOTAL		156000		-7360200	163319943600	39406381200

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

$$= 163319943600 + 39406381200 = 202726324800 \text{ mm}^4$$

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

$$= -7360200 / 156000 = -47.18 \text{ mm}$$

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

$$= 202726324800 - 156000 \times (-47.18)^2 = 202379064902 \text{ mm}^4$$

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

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

$$= 144871610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 12.000 / 2 + 14.000 / 2 = 2713.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2713^2) / (2 \times 2713/12 + 2512/12 + 2512/14) \\
&= 220922393940 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

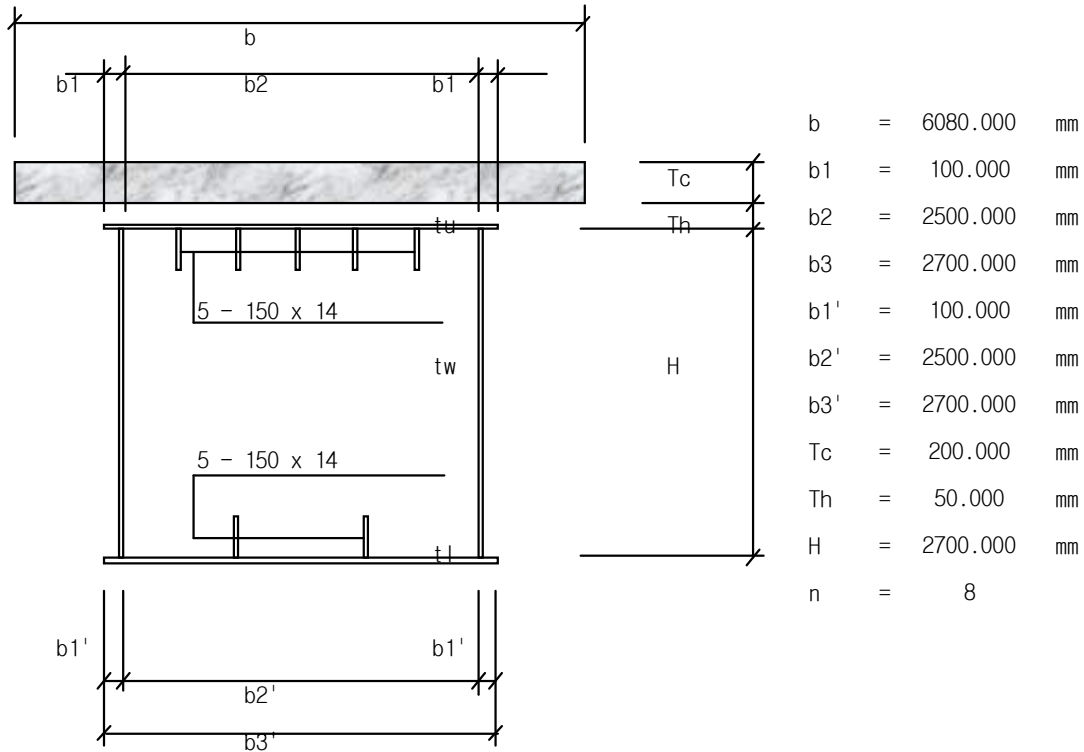
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 156000 + 1216000 / 8 = 308000 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 47.181 + 50.000 + 200.000 / 2 = 1547.18 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1547.181 \times 156000 / 308000 = 783.64 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1547.181 - 783.637 = 763.54 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 202379064902 + 4053333333 / 8 + 156000 \times 763.544^2 \\
&\quad + 1216000 / 8 \times 783.637^2 = 387174805285 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 144871610400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 613112677067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 12.000 + 200.000 / 8 = 37.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2713^2) / (2 \times 2713/12 + 2512/37 + 2512/14) \\
&= 265594526573 \text{ mm}^4
\end{aligned}$$

- 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 10.0	27000	1355.00	36585000	49572675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 14.0	37800	-1357.00	-51294600	69606772200	617400
TOTAL		150600		-14709600	153317572200	39406217400

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

$$= 153317572200 + 39406217400 = 192723789600 \text{ mm}^4$$

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

$$= -14709600 / 150600 = -97.67 \text{ mm}$$

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

$$= 192723789600 - 150600 \times (-97.67)^2 = 191287054327 \text{ mm}^4$$

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

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

$$= 141591110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 14.000 / 2 = 2712.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2712^2) / (2 \times 2712/12 + 2512/10 + 2512/14) \\
&= 210329723076 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

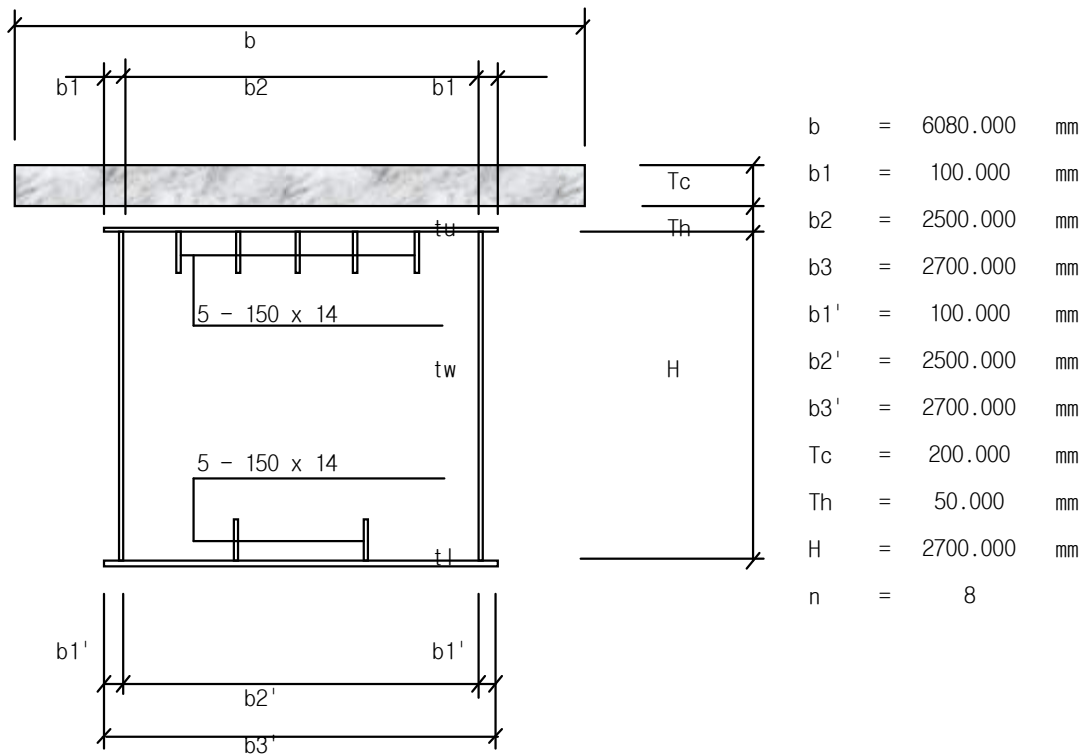
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 150600 + 1216000 / 8 = 302600 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - -97.673 + 50.000 + 200.000 / 2 = 1597.67 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1597.673 \times 150600 / 302600 = 795.14 \text{ mm} \\
dvs &= dv - dvc = 1597.673 - 795.141 = 802.53 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 191287054327 + 4053333333 / 8 + 150600 \times 802.533^2 \\
&\quad + 1216000 / 8 \times 795.141^2 = 384890751269 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 141591110400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 609832177067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2712^2) / (2 \times 2712/12 + 2512/35 + 2512/14) \\
&= 263997472992 \text{ mm}^4
\end{aligned}$$

- Section G2-9



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 10.0	27000	1355.00	36585000	49572675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1356.00	-43934400	59575046400	388800
TOTAL		145200		-7349400	143285846400	39405988800

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

$$= 143285846400 + 39405988800 = 182691835200 \text{ mm}^4$$

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

$$= -7349400 / 145200 = -50.62 \text{ mm}$$

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

$$= 182691835200 - 145200 \times (-50.616)^2 = 182319840156 \text{ mm}^4$$

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

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

$$= 138310610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 12.000 / 2 = 2711.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/10 + 2512/12) \\
&= 203324113146 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

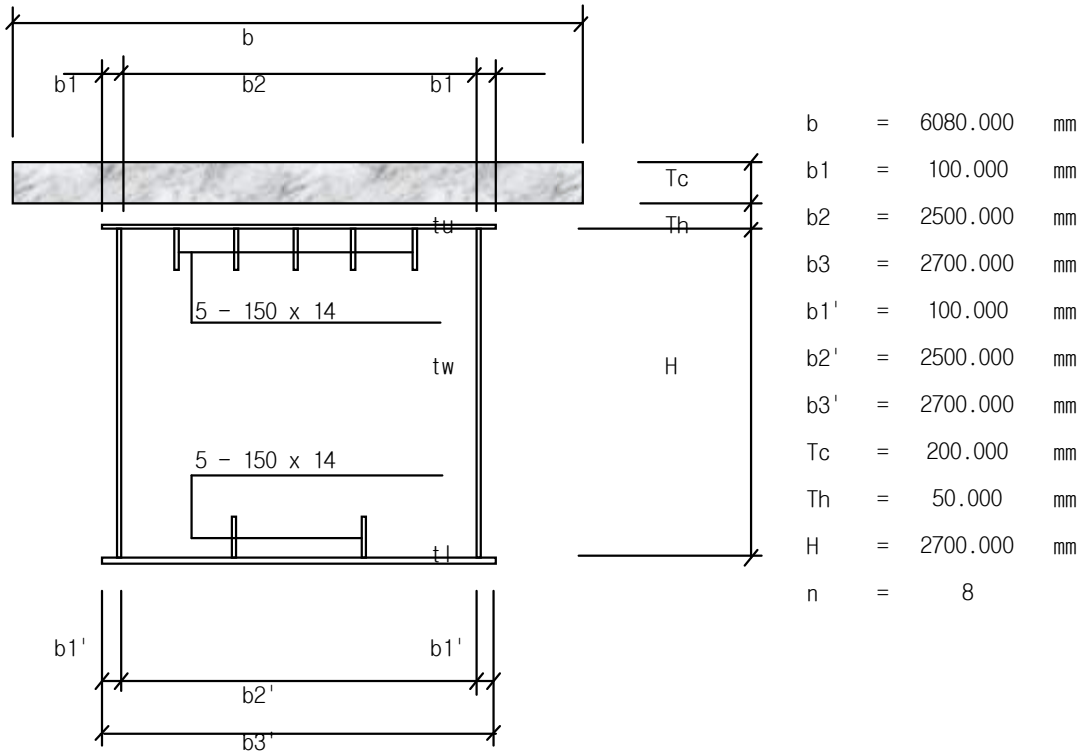
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 145200 + 1216000 / 8 = 297200 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 50.616 + 50.000 + 200.000 / 2 = 1550.62 \text{ mm} \\
d_{vc} &= d_v \cdot \sum A_s / A_v \\
&= 1550.616 \times 145200 / 297200 = 757.57 \text{ mm} \\
d_{vs} &= d_v - d_{vc} = 1550.616 - 757.569 = 793.05 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
&= 182319840156 + 4053333333 / 8 + 145200 \times 793.047^2 \\
&\quad + 1216000 / 8 \times 757.569^2 = 361380576966 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 138310610400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 606551677067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/35 + 2512/12) \\
&= 253099333449 \text{ mm}^4
\end{aligned}$$

- Section G2-10



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 20.0	54000	1360.00	73440000	99878400000	1800000
UPPER RIB	5	-	150.0	X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2	-	2700.0	X 12.0	64800				39366000000
LOWER RIB	5	-	150.0	X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1	-	2700.0	X 12.0	32400	-1356.00	-43934400	59575046400	388800
TOTAL					172200		29505600	193591571400	39407563800

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

$$= 193591571400 + 39407563800 = 232999135200 \text{ mm}^4$$

$$\delta s = \frac{\sum AsY}{\sum As} = \frac{29505600}{172200} = 171.34 \text{ mm}$$

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

$$= 232999135200 - 172200 \times 171.345^2 = 227943499710 \text{ mm}^4$$

$$\begin{aligned}
 I_{22} &= (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2 \\
 &= (2700^3 \times 20 / 12) + (2700^3 \times 12 / 12) + ((2700 \times 12^3 / 12) \\
 &\quad + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 154713110400 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 20.000 / 2 + 12.000 / 2 = 2716.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/20 + 2512/12) \\
&= 236403055350 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

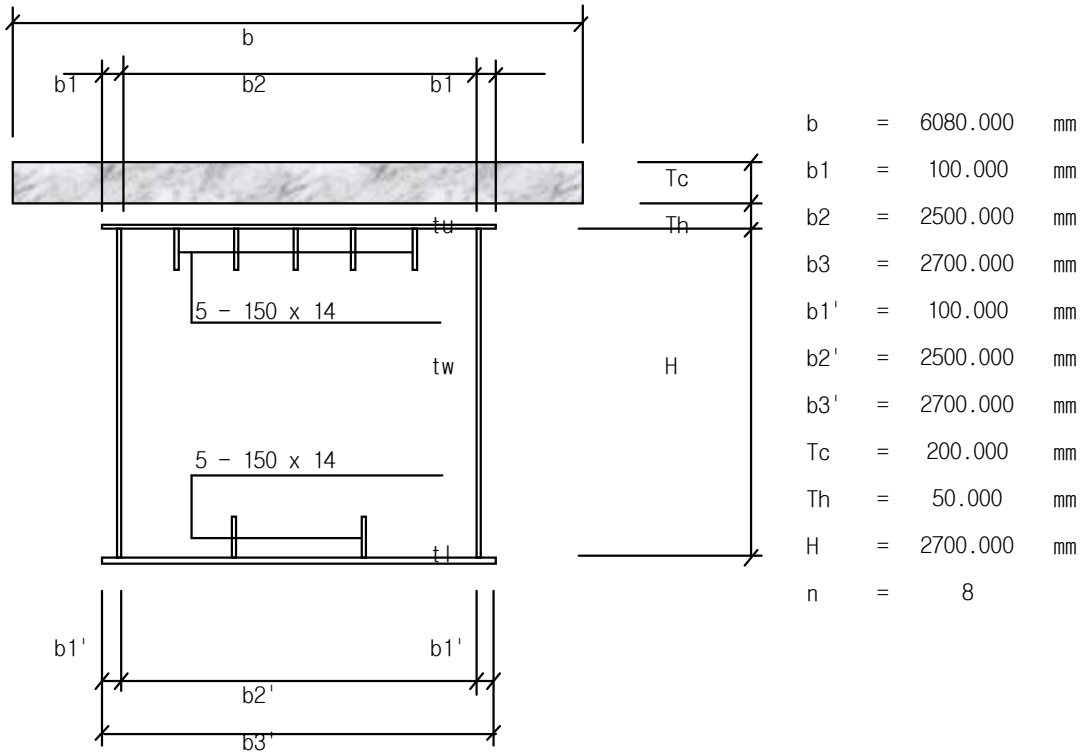
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c / N \\
&= 172200 + 1216000 / 8 = 324200 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 171.345 + 50.000 + 200.000 / 2 = 1328.66 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1328.655 \times 172200 / 324200 = 705.72 \text{ mm} \\
dvs &= dv - dvc = 1328.655 - 705.720 = 622.94 \text{ mm} \\
I_{v33} &= I_{33} + I_c / N + \sum A_s \cdot dvs^2 + A_c / N \cdot dvc^2 \\
&= 227943499710 + 4053333333 / 8 + 172200 \times 622.935^2 \\
&\quad + 1216000 / 8 \times 705.720^2 = 370974234836 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 154713110400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 622954177067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 20.000 + 200.000 / 8 = 45.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/45 + 2512/12) \\
&= 259383229760 \text{ mm}^4
\end{aligned}$$

- Section G2-11



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 20.0	54000	1360.00	73440000	99878400000	1800000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1361.00	-80843400	110027867400	2395800
TOTAL		199200		-7403400	244044392400	39409570800

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

$$= 244044392400 + 39409570800 = 283453963200 \text{ mm}^4$$

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

$$= -7403400 / 199200 = -37.17 \text{ mm}$$

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

$$= 283453963200 - 199200 \times (-37.166)^2 = 283178810933 \text{ mm}^4$$

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

$$= (2700^3 \times 20 / 12) + (2700^3 \times 22 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 171115610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 20.000 / 2 + 22.000 / 2 = 2721.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2721^2) / (2 \times 2721/12 + 2512/20 + 2512/22) \\
&= 269554467680 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

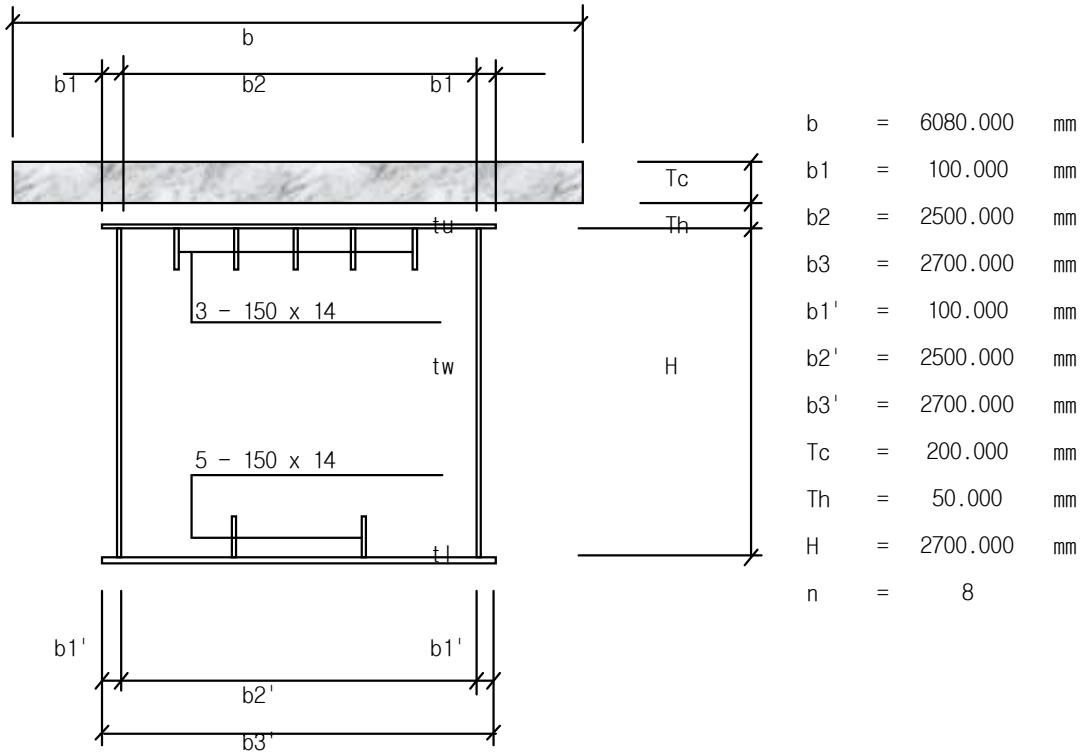
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 199200 + 1216000 / 8 = 351200 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - -37.166 + 50.000 + 200.000 / 2 = 1537.17 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1537.166 \times 199200 / 351200 = 871.88 \text{ mm} \\
dvs &= dv - dvc = 1537.166 - 871.878 = 665.29 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 283178810933 + 4053333333 / 8 + 199200 \times 665.288^2 \\
&\quad + 1216000 / 8 \times 871.878^2 = 487398955802 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 171115610400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 639356677067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 20.000 + 200.000 / 8 = 45.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2721^2) / (2 \times 2721/12 + 2512/45 + 2512/22) \\
&= 299720930968 \text{ mm}^4
\end{aligned}$$

- Section G2-12



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 20.0	54000	1360.00	73440000	99878400000	1800000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1361.00	-80843400	110027867400	2395800
TOTAL		195000		-12758400	237216767400	39401695800

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

$$= 237216767400 + 39401695800 = 276618463200 \text{ mm}^4$$

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

$$= -12758400 / 195000 = -65.43 \text{ mm}$$

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

$$= 276618463200 - 195000 \times (-65.428)^2 = 275783710530 \text{ mm}^4$$

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

$$= (2700^3 \times 20 / 12) + (2700^3 \times 22 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 171115610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 20.000 / 2 + 22.000 / 2 = 2721.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2721^2) / (2 \times 2721/12 + 2512/20 + 2512/22) \\
&= 269554467680 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

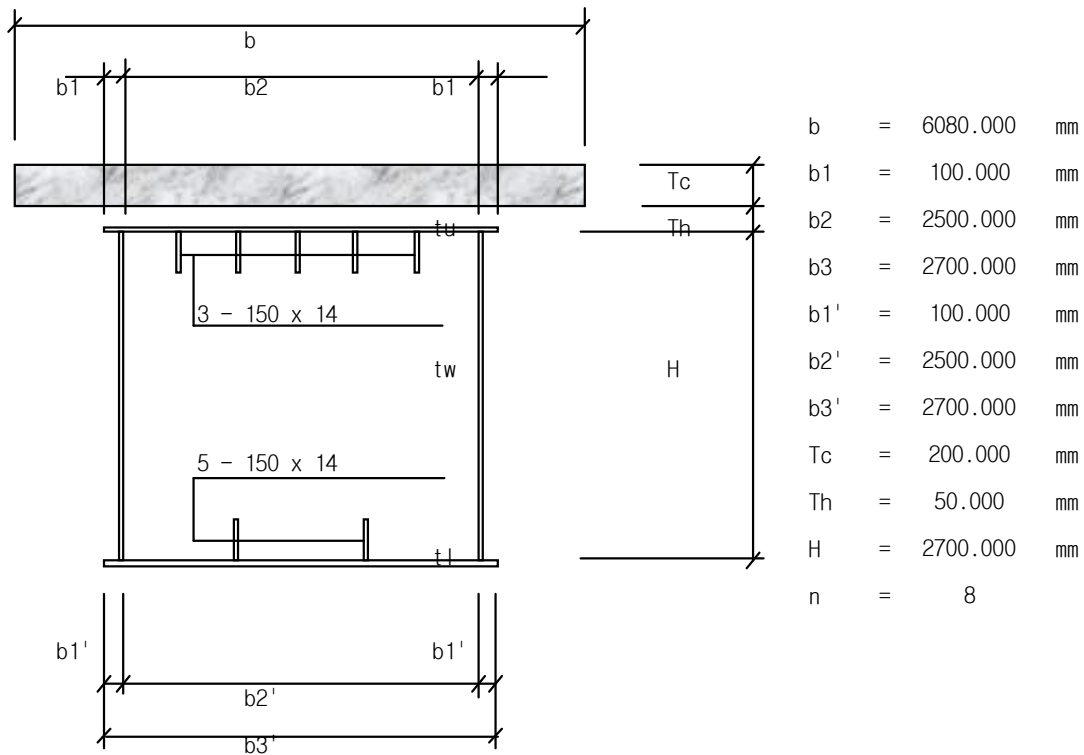
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 195000 + 1216000 / 8 = 347000 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 65.428 + 50.000 + 200.000 / 2 = 1565.43 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1565.428 \times 195000 / 347000 = 879.71 \text{ mm} \\
dvs &= dv - dvc = 1565.428 - 879.707 = 685.72 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 275783710530 + 4053333333 / 8 + 195000 \times 685.720^2 \\
&\quad + 1216000 / 8 \times 879.707^2 = 485612316119 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 171115610400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 639356677067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 20.000 + 200.000 / 8 = 45.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2721^2) / (2 \times 2721/12 + 2512/45 + 2512/22) \\
&= 299720930968 \text{ mm}^4
\end{aligned}$$

- Section G2-13



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 30.0	81000	1365.00	110565000	150921225000	6075000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1361.00	-80843400	110027867400	2395800
TOTAL		222000		24366600	288259592400	39405970800

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

$$= 288259592400 + 39405970800 = 327665563200 \text{ mm}^4$$

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

$$= 24366600 / 222000 = 109.76 \text{ mm}$$

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

$$= 327665563200 - 222000 \times 109.759^2 = 324991098355 \text{ mm}^4$$

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

$$= (2700^3 \times 30 / 12) + (2700^3 \times 22 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 187518110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 30.000 / 2 + 22.000 / 2 = 2726.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2726^2) / (2 \times 2726/12 + 2512/30 + 2512/22) \\
&= 287566231117 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

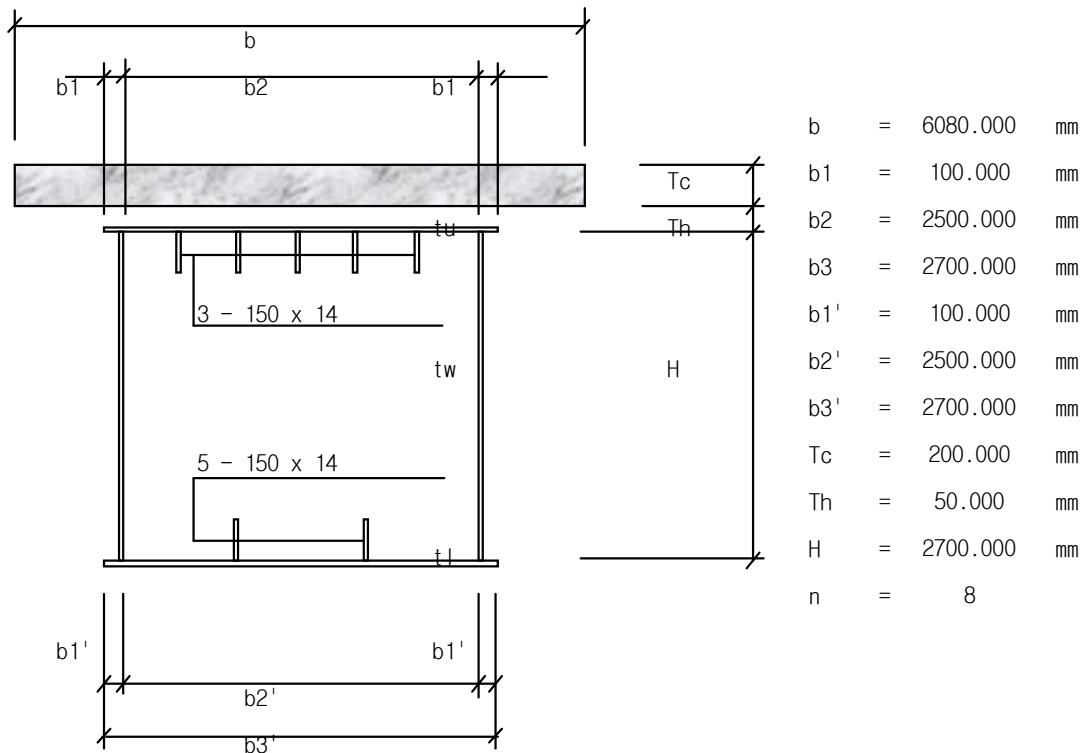
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 222000 + 1216000 / 8 = 374000 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 109.759 + 50.000 + 200.000 / 2 = 1390.24 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1390.241 \times 222000 / 374000 = 825.22 \text{ mm} \\
dvs &= dv - dvc = 1390.241 - 825.223 = 565.02 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 324991098355 + 4053333333 / 8 + 222000 \times 565.018^2 \\
&\quad + 1216000 / 8 \times 825.223^2 = 499881051269 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 187518110400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 655759177067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 30.000 + 200.000 / 8 = 55.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2726^2) / (2 \times 2726/12 + 2512/55 + 2512/22) \\
&= 305386421676 \text{ mm}^4
\end{aligned}$$

- Section G2-14



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 30.0	81000	1365.00	110565000	150921225000	6075000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 32.0	86400	-1366.00	-118022400	161218598400	7372800
TOTAL		249000		-12812400	339450323400	39410947800

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

$$= 339450323400 + 39410947800 = 378861271200 \text{ mm}^4$$

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

$$= -12812400 / 249000 = -51.46 \text{ mm}$$

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

$$= 378861271200 - 249000 \times (-51.455)^2 = 378202003755 \text{ mm}^4$$

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

$$= (2700^3 \times 30 / 12) + (2700^3 \times 32 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 203920610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 30.000 / 2 + 32.000 / 2 = 2731.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2731^2) / (2 \times 2731/12 + 2512/30 + 2512/32) \\
&= 304913067146 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

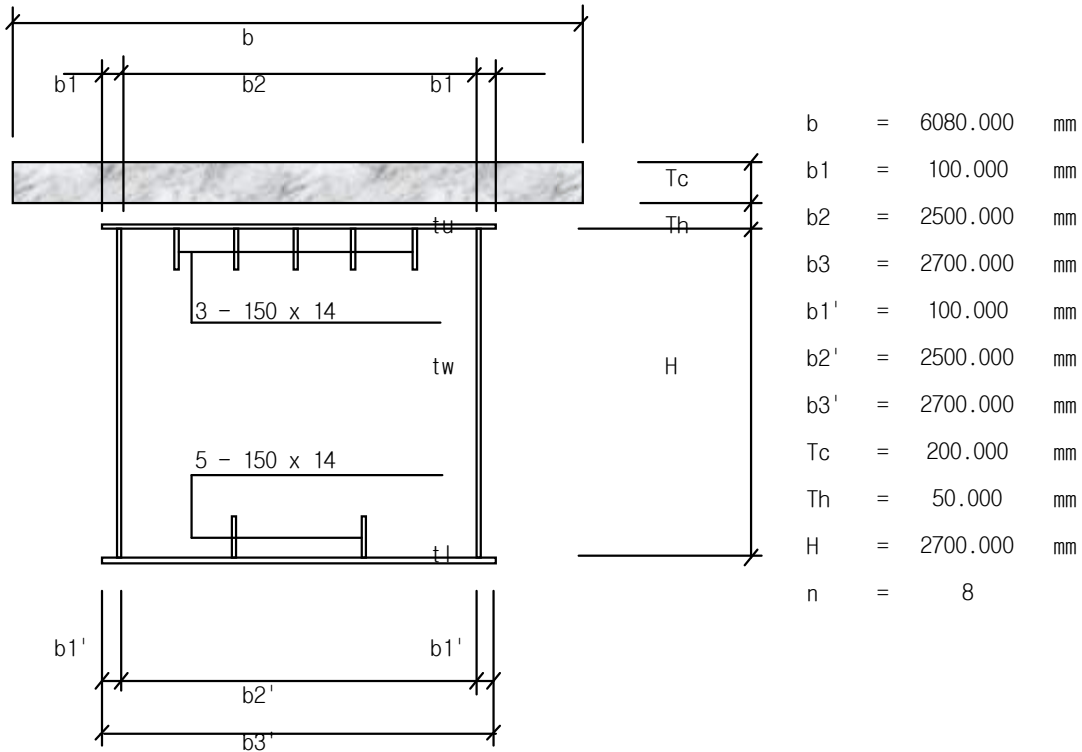
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 249000 + 1216000 / 8 = 401000 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 51.455 + 50.000 + 200.000 / 2 = 1551.46 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1551.455 \times 249000 / 401000 = 963.37 \text{ mm} \\
dvs &= dv - dvc = 1551.455 - 963.373 = 588.08 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 378202003755 + 4053333333 / 8 + 249000 \times 588.083^2 \\
&\quad + 1216000 / 8 \times 963.373^2 = 605892368805 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 203920610400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 672161677067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 30.000 + 200.000 / 8 = 55.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2731^2) / (2 \times 2731/12 + 2512/55 + 2512/32) \\
&= 324944807181 \text{ mm}^4
\end{aligned}$$

- Section G2-15



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 20.0	54000	1360.00	73440000	99878400000	1800000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 32.0	86400	-1366.00	-118022400	161218598400	7372800
TOTAL		222000		-49937400	288407498400	39406672800

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

$$= 288407498400 + 39406672800 = 327814171200 \text{ mm}^4$$

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

$$= -49937400 / 222000 = -224.94 \text{ mm}$$

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

$$= 327814171200 - 222000 \times (-224.94)^2 = 316581090485 \text{ mm}^4$$

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

$$= (2700^3 \times 20 / 12) + (2700^3 \times 32 / 12) + ((2700 \times 12^3 / 12) + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2$$

$$= 187518110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
 H_k &= H + t_u / 2 + t_l / 2 \\
 &= 2700.000 + 20.000 / 2 + 32.000 / 2 = 2726.00 \text{ mm} \\
 K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
 &= (4 \times 2512^2 \times 2726^2) / (2 \times 2726/12 + 2512/20 + 2512/32) \\
 &= 284865041067 \text{ mm}^4
 \end{aligned}$$

② 합성후 단면

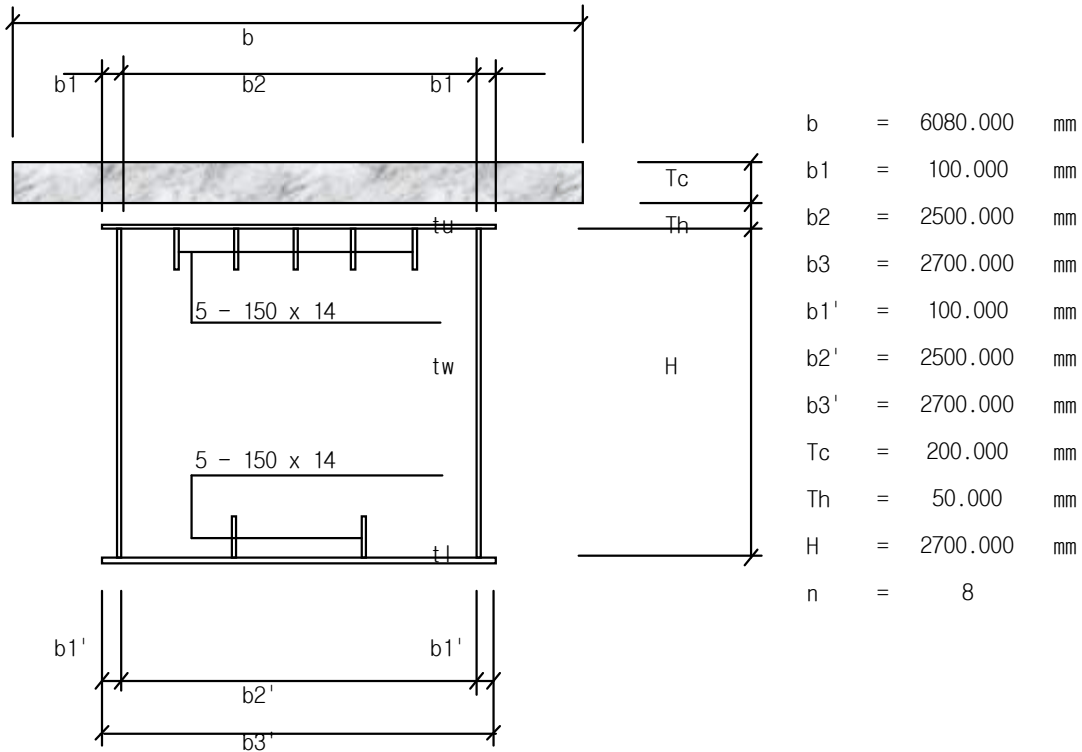
$$\begin{aligned}
 A_c &= b \times T_c \\
 &= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
 A_v &= \sum A_s + A_c/N \\
 &= 222000 + 1216000 / 8 = 374000 \text{ mm}^2 \\
 I_c &= b \times T_c^3 / 12 \\
 &= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
 d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
 &= 2700.000 / 2 - -224.943 + 50.000 + 200.000 / 2 = 1724.94 \text{ mm} \\
 d_{vc} &= d_v \cdot \sum A_s / A_v \\
 &= 1724.943 \times 222000 / 374000 = 1023.90 \text{ mm} \\
 d_{vs} &= d_v - d_{vc} = 1724.943 - 1023.897 = 701.05 \text{ mm} \\
 I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
 &= 316581090485 + 4053333333 / 8 + 222000 \times 701.046^2 \\
 &\quad + 1216000 / 8 \times 1023.897^2 = 585544662683 \text{ mm}^4 \\
 I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
 &= 187518110400 + 6080.000^3 \\
 &\quad \times 200.000 / 12 / 8 = 655759177067 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
 t_{cu} &= t_u + T_c / N \\
 &= 20.000 + 200.000 / 8 = 45.00 \text{ mm} \\
 K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
 &= (4 \times 2512^2 \times 2726^2) / (2 \times 2726/12 + 2512/45 + 2512/32) \\
 &= 318632240484 \text{ mm}^4
 \end{aligned}$$

- 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 10.0	27000	1355.00	36585000	49572675000	225000
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1361.00	-80843400	110027867400	2395800
TOTAL		172200		-44258400	193738667400	39407995800

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

$$= 193738667400 + 39407995800 = 233146663200 \text{ mm}^4$$

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

$$= -44258400 / 172200 = -257.02 \text{ mm}$$

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

$$= 233146663200 - 172200 \times (-257.017)^2 = 221771483348 \text{ mm}^4$$

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

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

$$= 154713110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 22.000 / 2 = 2716.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/10 + 2512/22) \\
&= 227603925491 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

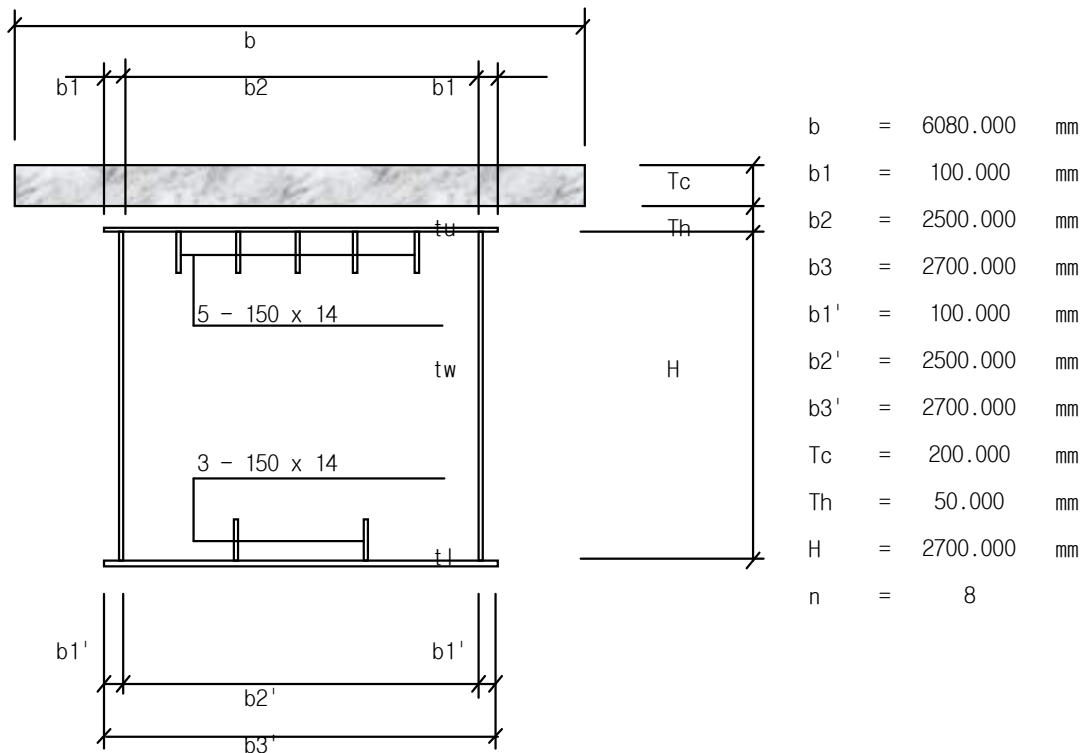
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 172200 + 1216000 / 8 = 324200 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - -257.017 + 50.000 + 200.000 / 2 = 1757.02 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1757.017 \times 172200 / 324200 = 933.25 \text{ mm} \\
dvs &= dv - dvc = 1757.017 - 933.246 = 823.77 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 221771483348 + 4053333333 / 8 + 172200 \times 823.771^2 \\
&\quad + 1216000 / 8 \times 933.246^2 = 471517069624 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 154713110400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 622954177067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/35 + 2512/22) \\
&= 291552208882 \text{ mm}^4
\end{aligned}$$

– Section G2-17



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	10.0	27000	1355.00	36585000	49572675000	225000
UPPER RIB	5	-	150.0	X	14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2	-	2700.0	X	12.0	64800				39366000000
LOWER RIB	3	-	150.0	X	14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1	-	2700.0	X	12.0	32400	-1356.00	-43934400	59575046400	388800
TOTAL						141000		-1994400	136458221400	39398113800

$$I_{S'} = \sum A_S Y^2 + \sum I_0$$

$$= 136458221400 + 39398113800 = 175856335200 \text{ mm}^4$$

$$\delta s = \frac{\sum AsY}{\sum As} = \frac{-1994400}{141000} = -14.14 \text{ mm}$$

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

$$= 175856335200 - 141000 \times -14.145^2 = 175828125049 \text{ mm}^4$$

$$\begin{aligned}
 I_{22} &= (b_3^3 \times t_u / 12) + (b_3'^3 \times t_l / 12) + ((H \times t_w^3 / 12) + (H \times t_w \times (b_2 / 2 + t_w / 2)^2)) \times 2 \\
 &= (2700^3 \times 10 / 12) + (2700^3 \times 12 / 12) + ((2700 \times 12^3 / 12) \\
 &\quad + (2700 \times 12 \times (2500 / 2 + 12 / 2)^2)) \times 2 = 138310610400 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 12.000 / 2 = 2711.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/10 + 2512/12) \\
&= 203324113146 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

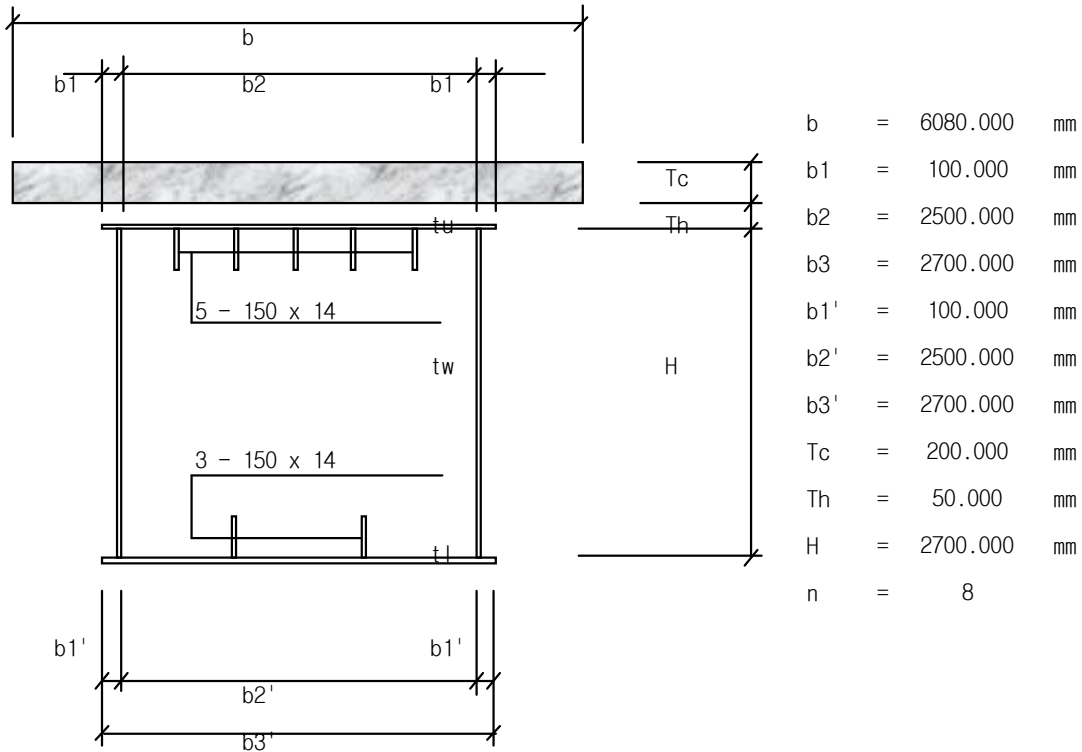
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c / N \\
&= 141000 + 1216000 / 8 = 293000 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 14.145 + 50.000 + 200.000 / 2 = 1514.14 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1514.145 \times 141000 / 293000 = 728.65 \text{ mm} \\
dvs &= dv - dvc = 1514.145 - 728.650 = 785.49 \text{ mm} \\
I_{v33} &= I_{33} + I_c / N + \sum A_s \cdot dvs^2 + A_c / N \cdot dvc^2 \\
&= 175828125049 + 4053333333 / 8 + 141000 \times 785.495^2 \\
&\quad + 1216000 / 8 \times 728.650^2 = 344033543739 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 138310610400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 606551677067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/35 + 2512/12) \\
&= 253099333449 \text{ mm}^4
\end{aligned}$$

- Section G2-18



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 12.0	32400	1356.00	43934400	59575046400	388800
UPPER RIB	5 - 150.0 X 14.0	10500	1275.00	13387500	17069062500	19687500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	3 - 150.0 X 14.0	6300	-1275.00	-8032500	10241437500	11812500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1356.00	-43934400	59575046400	388800
TOTAL		146400		5355000	146460592800	39398277600

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

$$= 146460592800 + 39398277600 = 185858870400 \text{ mm}^4$$

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

$$= 5355000 / 146400 = 36.58 \text{ mm}$$

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

$$= 185858870400 - 146400 \times 36.58^2 = 185662995912 \text{ mm}^4$$

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

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

$$= 141591110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
 H_k &= H + t_u / 2 + t_l / 2 \\
 &= 2700.000 + 12.000 / 2 + 12.000 / 2 = 2712.00 \text{ mm} \\
 K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
 &= (4 \times 2512^2 \times 2712^2) / (2 \times 2712/12 + 2512/12 + 2512/12) \\
 &= 213219398554 \text{ mm}^4
 \end{aligned}$$

② 합성후 단면

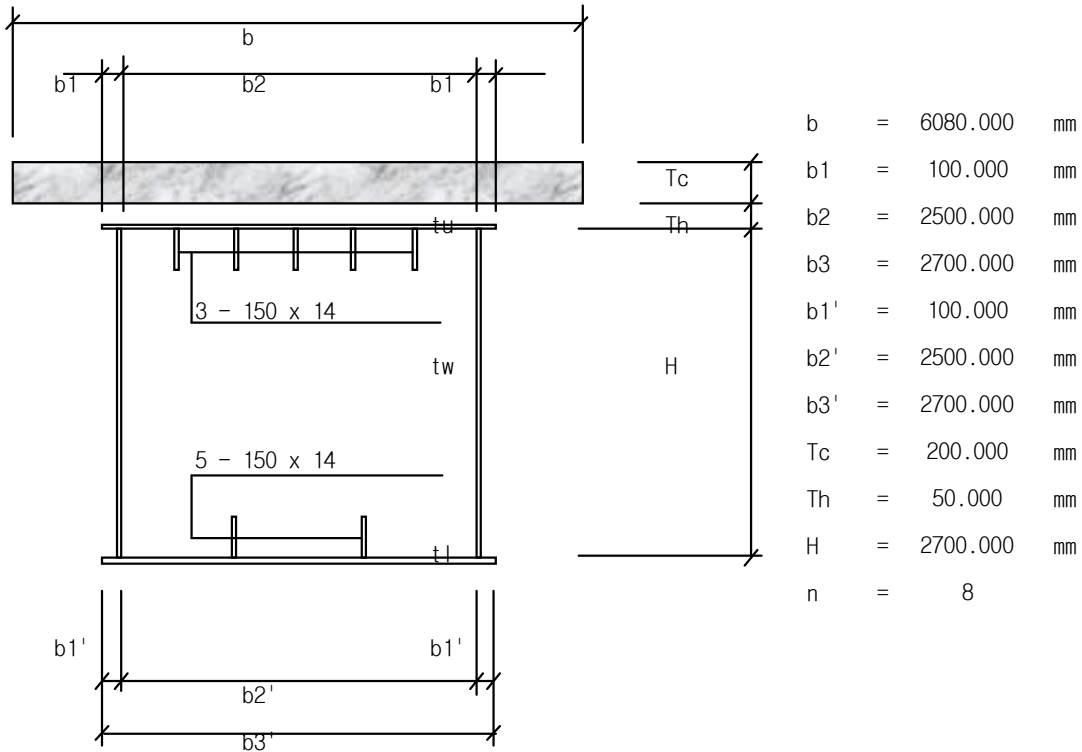
$$\begin{aligned}
 A_c &= b \times T_c \\
 &= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
 A_v &= \sum A_s + A_c/N \\
 &= 146400 + 1216000 / 8 = 298400 \text{ mm}^2 \\
 I_c &= b \times T_c^3 / 12 \\
 &= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
 d_v &= H / 2 - \delta_s + T_h + T_c / 2 \\
 &= 2700.000 / 2 - 36.578 + 50.000 + 200.000 / 2 = 1463.42 \text{ mm} \\
 d_{vc} &= d_v \cdot \sum A_s / A_v \\
 &= 1463.422 \times 146400 / 298400 = 717.98 \text{ mm} \\
 d_{vs} &= d_v - d_{vc} = 1463.422 - 717.979 = 745.44 \text{ mm} \\
 I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot d_{vs}^2 + A_c/N \cdot d_{vc}^2 \\
 &= 185662995912 + 4053333333 / 8 + 146400 \times 745.443^2 \\
 &\quad + 1216000 / 8 \times 717.979^2 = 345877078538 \text{ mm}^4 \\
 I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
 &= 141591110400 + 6080.000^3 \\
 &\quad \times 200.000 / 12 / 8 = 609832177067 \text{ mm}^4
 \end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
 t_{cu} &= t_u + T_c / N \\
 &= 12.000 + 200.000 / 8 = 37.00 \text{ mm} \\
 K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
 &= (4 \times 2512^2 \times 2712^2) / (2 \times 2712/12 + 2512/37 + 2512/12) \\
 &= 254575701150 \text{ mm}^4
 \end{aligned}$$

- 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	1355.00	36585000	49572675000	225000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 12.0	32400	-1356.00	-43934400	59575046400	388800
TOTAL		141000		-12704400	136458221400	39398113800

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

$$= 136458221400 + 39398113800 = 175856335200 \text{ mm}^4$$

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

$$= -12704400 / 141000 = -90.10 \text{ mm}$$

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

$$= 175856335200 - 141000 \times (-90.10)^2 = 174711641729 \text{ mm}^4$$

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

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

$$= 138310610400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 12.000 / 2 = 2711.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/10 + 2512/12) \\
&= 203324113146 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

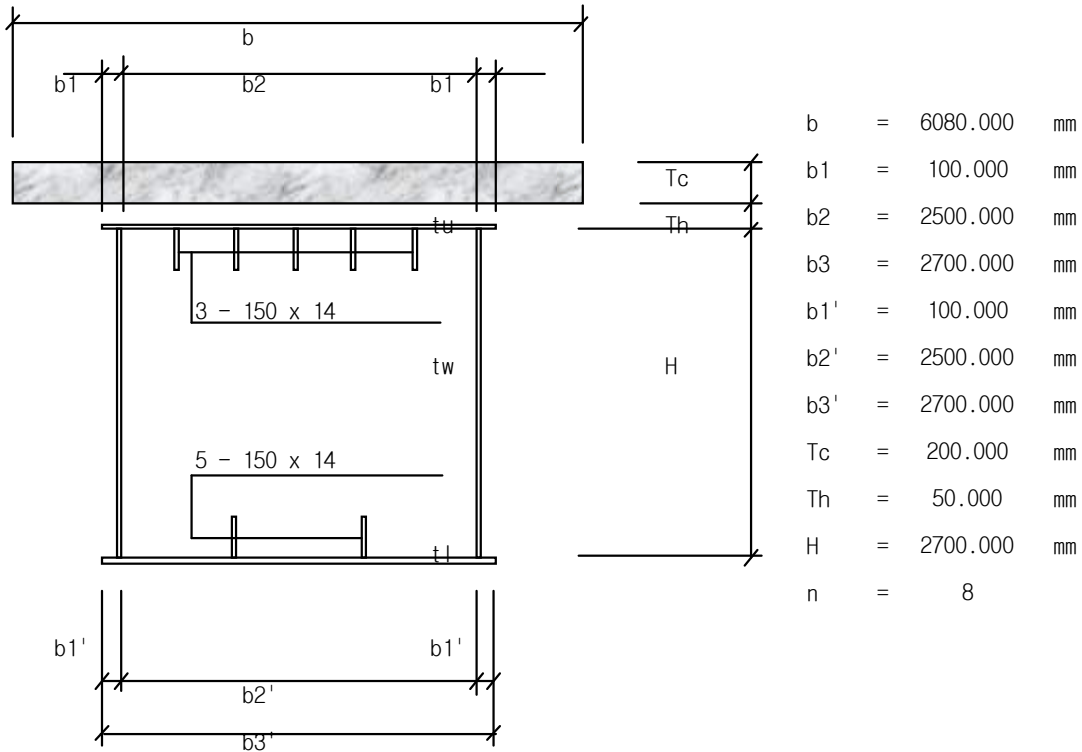
$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c / N \\
&= 141000 + 1216000 / 8 = 293000 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - 90.102 + 50.000 + 200.000 / 2 = 1590.10 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1590.102 \times 141000 / 293000 = 765.20 \text{ mm} \\
dvs &= dv - dvc = 1590.102 - 765.203 = 824.90 \text{ mm} \\
I_{v33} &= I_{33} + I_c / N + \sum A_s \cdot dvs^2 + A_c / N \cdot dvc^2 \\
&= 174711641729 + 4053333333 / 8 + 141000 \times 824.899^2 \\
&\quad + 1216000 / 8 \times 765.203^2 = 360164382824 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 138310610400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 606551677067 \text{ mm}^4
\end{aligned}$$

- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2711^2) / (2 \times 2711/12 + 2512/35 + 2512/12) \\
&= 253099333449 \text{ mm}^4
\end{aligned}$$

- 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 10.0	27000	1355.00	36585000	49572675000	225000
UPPER RIB	3 - 150.0 X 14.0	6300	1275.00	8032500	10241437500	11812500
W E B	2 - 2700.0 X 12.0	64800				39366000000
LOWER RIB	5 - 150.0 X 14.0	10500	-1275.00	-13387500	17069062500	19687500
LOWER FL.	1 - 2700.0 X 22.0	59400	-1361.00	-80843400	110027867400	2395800
TOTAL		168000		-49613400	186911042400	39400120800

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

$$= 186911042400 + 39400120800 = 226311163200 \text{ mm}^4$$

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

$$= -49613400 / 168000 = -295.32 \text{ mm}$$

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

$$= 226311163200 - 168000 \times (-295.318)^2 = 211659440226 \text{ mm}^4$$

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

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

$$= 154713110400 \text{ mm}^4$$

- 비틀림 강성

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

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

$$\begin{aligned}
H_k &= H + t_u / 2 + t_l / 2 \\
&= 2700.000 + 10.000 / 2 + 22.000 / 2 = 2716.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_u + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/10 + 2512/22) \\
&= 227603925491 \text{ mm}^4
\end{aligned}$$

② 합성후 단면

$$\begin{aligned}
A_c &= b \times T_c \\
&= 6080.000 \times 200.000 = 1216000 \text{ mm}^2 \\
A_v &= \sum A_s + A_c/N \\
&= 168000 + 1216000 / 8 = 320000 \text{ mm}^2 \\
I_c &= b \times T_c^3 / 12 \\
&= 6080.000 \times 200.000^3 / 12 = 4053333333 \text{ mm}^4 \\
dv &= H / 2 - \delta_s + T_h + T_c / 2 \\
&= 2700.000 / 2 - -295.318 + 50.000 + 200.000 / 2 = 1795.32 \text{ mm} \\
dvc &= dv \cdot \sum A_s / A_v \\
&= 1795.318 \times 168000 / 320000 = 942.54 \text{ mm} \\
dvs &= dv - dvc = 1795.318 - 942.542 = 852.78 \text{ mm} \\
I_{v33} &= I_{33} + I_c/N + \sum A_s \cdot dvs^2 + A_c/N \cdot dvc^2 \\
&= 211659440226 + 4053333333 / 8 + 168000 \times 852.776^2 \\
&\quad + 1216000 / 8 \times 942.542^2 = 469374770306 \text{ mm}^4 \\
I_{v22} &= I_{22} + b^3 \times T_c / 12 / N \\
&= 154713110400 + 6080.000^3 \\
&\quad \times 200.000 / 12 / 8 = 622954177067 \text{ mm}^4
\end{aligned}$$

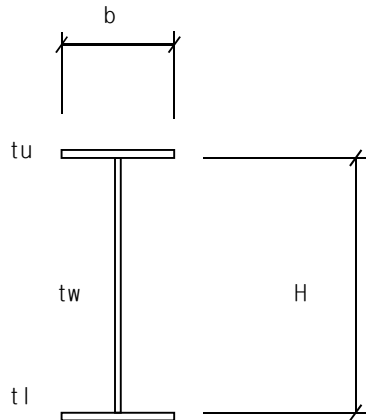
- 비틀림 강성

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

$$\begin{aligned}
t_{cu} &= t_u + T_c / N \\
&= 10.000 + 200.000 / 8 = 35.00 \text{ mm} \\
K &= (4 \times b k^2 \times H_k^2) / (2 \times H_k / t_w + b k / t_{cu} + b k / t_l) \\
&= (4 \times 2512^2 \times 2716^2) / (2 \times 2716/12 + 2512/35 + 2512/22) \\
&= 291552208882 \text{ mm}^4
\end{aligned}$$

2-2. 가로보 및 세로보 단면상수 산정

- 가로보 Section 1 : 교대 및 교각



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

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

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

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

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

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

구분	규격	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				8000000000
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.

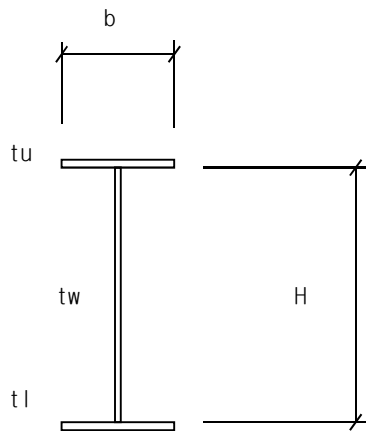
여기서, L, I : 실제 가로보의 길이 및 강성 L', I' : 모델링시 가로보의 길이 및 보정강성

- 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	규	격	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
W E B	1500.00	X	10.00	15000.0			2812500000
LOWER FL.	300.00	X	10.00	3000.0	-755.00	-2265000	1710075000
TOTAL				21000.0		0	3420150000

$$\begin{aligned}
 I_{33} &= \sum AsY^2 + \sum I_o \\
 &= 3420150000 + 2812500000 = 6232700000 \text{ mm}^4 \\
 I_{22} &= (bu^3 \times tu / 12) + (bl^3 \times tl / 12) + (H \times tw^3 / 12) \\
 &= (300^3 \times 10 / 12) + (300^3 \times 10 / 12) + (1500 \times 10^3 / 12) \\
 &= 45125000 \text{ mm}^4
 \end{aligned}$$

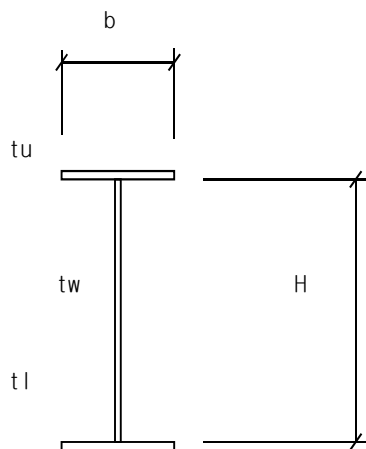
모델링시의 가로보 강성보정은 $I' = I \times (L' / L)^3$ 에 의한다.

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

- 비틀림 강성

$$\begin{aligned}
 K &= \sum (b \times t^3) / 3 \\
 &= (300 \times 10^3 + 300 \times 10^3 + 1500 \times 10^3) / 3 = 700000 \text{ mm}^4
 \end{aligned}$$

- 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.

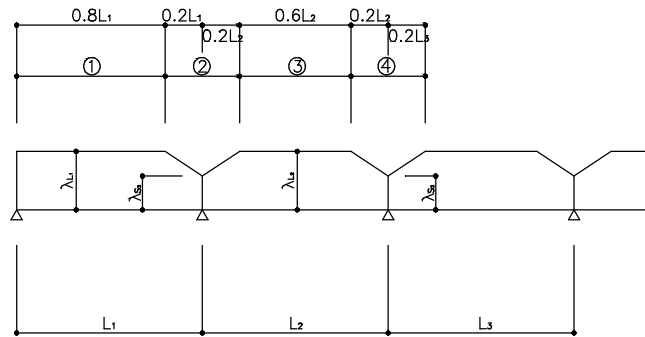
여기서, L, I : 실제 가로보의 길이 및 강성 L', I' : 모델링시 가로보의 길이 및 보정강성

- 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

$L_4 = 55.000$ m

1. 제 4, 7 경간 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 4, 5, 6 경간 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

$$\lambda_{S1} = \{1.06 - 3.2(b/l) + 4.5(b/l)^2\} \cdot b = 1.116 \text{ m}$$

$$\therefore \text{플랜지 유효폭} \quad B = 2 \times (\lambda S1 + b_e) = 2.432 \quad \text{m}$$

3. 제 5, 6 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

$$\lambda L_2 = b = 1.25 \text{ m}$$

$$\therefore \text{플랜지 유효폭} \quad B = 2 \times (\lambda L_2 + b_e) = 2.700 \text{ m}$$

· 하 부

$$b/l = 1.25 / 33 = 0.038$$

여기서, $b/l \leq 0.05$ 이므로

$$\lambda_{L2} = b = 1.25 \text{ m}$$

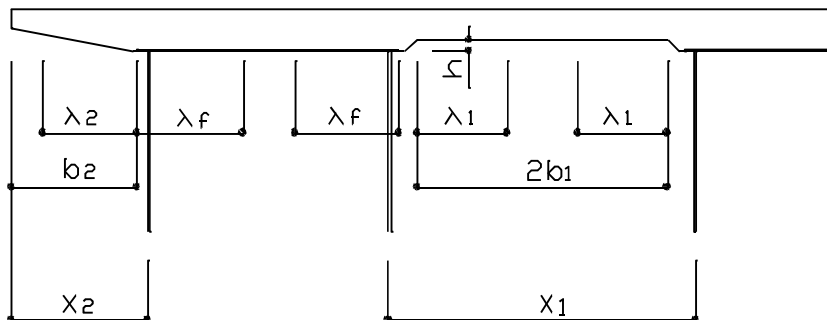
$$\therefore \text{플랜지 유효폭} \quad B = 2 \times (\lambda L_2 + b_e) = 2.700 \text{ m}$$

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

$X_2 = 0.930$: 외측 GIRDER 복부에서 캔틸레버 끝단까지의 거리

$h = 0.100$: 현치 높이

be = 0.100 : 플랜지의 돌출폭

$$2b_1 = X_1 - 2(b_e + h) = 5.3 - 2 \times (0.1 + 0.1) = 4.900 \text{ m}$$

$$b_2 = x_2 - b_e = 0.93 - 0.1 = 0.830 \text{ m}$$

1. 제 4, 7 경간 정모멘트부

$$l = 0.8 \times L1 = 0.8 \times 55 = 44.000 \text{ m}$$

$$b1 / l = 2.45 / 44 = 0.056$$

여기서, $0.05 < b/l < 0.30$ 이므로

$$\lambda 1 = \{1.1 - 2(b/l)\} \cdot b = 2.422 \text{ m}$$

$$b2 / l = 0.83 / 44 = 0.019$$

여기서, $b/l \leq 0.05$ 이므로

$$\lambda 2 = b = 0.83 \text{ m}$$

슬래브 유효폭

$$B = \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 6.052 \text{ m}$$

2. 제 4, 5, 6 경간 부모멘트부

$$l = 0.2 \times (L1 + L2) = 0.2 \times (55 + 55) = 22.000 \text{ m}$$

$$b1 / l = 2.45 / 22 = 0.111$$

여기서, $0.02 < b/l < 0.30$ 이므로

$$\lambda 1 = \{1.06 - 3.2(b/l) + 4.5(b/l)^2\} \cdot b = 1.861 \text{ m}$$

$$b2 / l = 0.83 / 22 = 0.038$$

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

$$B = \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 5.178 \text{ m}$$

3. 제 5, 6 경간 정모멘트부

$$l = 0.6 \times L2 = 0.6 \times 55 = 33.000 \text{ m}$$

$$b1 / l = 2.45 / 33 = 0.074$$

여기서, $0.05 < b/l < 0.30$ 이므로

$$\lambda 1 = \{1.1 - 2(b/l)\} \cdot b = 2.331 \text{ m}$$

$$b2 / l = 0.83 / 33 = 0.025$$

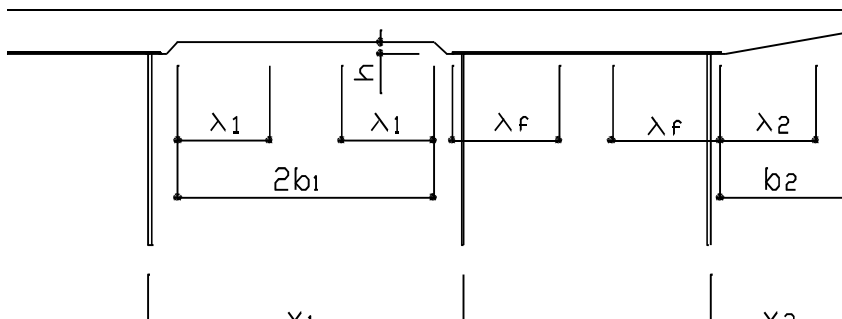
여기서, $b/l \leq 0.05$ 이므로

$$\lambda 2 = b = 0.83 \text{ m}$$

슬래브 유효폭

$$B = \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 5.961 \text{ m}$$

2) GIRDER - 2



$$\begin{aligned}
X1 &= 5.300 && \text{: 인접한 GIRDER의 복부사이의 간격} \\
X2 &= 0.920 && \text{: 외측 GIRDER 복부에서 캔틸레버 끝단까지의 거리} \\
h &= 0.100 && \text{: 현치 높이} \\
be &= 0.100 && \text{: 플랜지의 돌출폭} \\
2b1 &= X1 - 2(be + h) = 5.3 - 2 \times (0.1 + 0.1) && = 4.900 \quad \text{m} \\
b2 &= X2 - be = 0.92 - 0.1 && = 0.820 \quad \text{m}
\end{aligned}$$

1. 제 4, 5 경간 정모멘트부

$$\begin{aligned}
l &= 0.8 \times L1 = 0.8 \times 55 = 44.000 \quad \text{m} \\
b1 / l &= 2.45 / 44 = 0.056 \\
\text{여기서, } 0.05 &< b/l < 0.30 \text{ 이므로} \\
\lambda 1 &= \{1.1 - 2(b/l)\} \cdot b = 2.422 \quad \text{m} \\
b2 / l &= 0.82 / 44 = 0.019 \\
\text{여기서, } b/l &\leq 0.05 \text{ 이므로} \\
\lambda 2 &= b = 0.82 \quad \text{m} \\
\text{슬래브 유효폭} \\
B &= \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 6.042 \quad \text{m}
\end{aligned}$$

2. 제 4, 5, 6 경간 부모멘트부

$$\begin{aligned}
l &= 0.2 \times (L1 + L2) = 0.2 \times (55 + 55) = 22.000 \quad \text{m} \\
b1 / l &= 2.45 / 22 = 0.111 \\
\text{여기서, } 0.02 &< b/l < 0.30 \text{ 이므로} \\
\lambda 1 &= \{1.06 - 3.2(b/l) + 4.5(b/l)^2\} \cdot b = 1.861 \quad \text{m} \\
b2 / l &= 0.82 / 22 = 0.037 \\
\text{여기서, } 0.02 &< b/l < 0.30 \text{ 이므로} \\
\lambda 2 &= \{1.06 - 3.2(b/l) + 4.5(b/l)^2\} \cdot b = 0.777 \quad \text{m} \\
\text{슬래브 유효폭} \\
B &= \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 5.170 \quad \text{m}
\end{aligned}$$

3. 제 5, 6 경간 정모멘트부

$$\begin{aligned}
l &= 0.6 \times L2 = 0.6 \times 55 = 33.000 \quad \text{m} \\
b1 / l &= 2.45 / 33 = 0.074 \\
\text{여기서, } 0.05 &< b/l < 0.30 \text{ 이므로} \\
\lambda 1 &= \{1.1 - 2(b/l)\} \cdot b = 2.331 \quad \text{m} \\
b2 / l &= 0.82 / 33 = 0.025 \\
\text{여기서, } b/l &\leq 0.05 \text{ 이므로} \\
\lambda 2 &= b = 0.82 \quad \text{m} \\
\text{슬래브 유효폭} \\
B &= \text{플랜지 유효폭} + \lambda 1 + \lambda 2 + h = 5.951 \quad \text{m}
\end{aligned}$$

4. 부재력 요약

[4경간 정모멘트부]

[BENDING MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	12,882.160	3,188.440	7,179.830	568.093	0.53
G2	12,873.070	3,485.380	7,940.110	567.856	0.53

[SHEAR FORCE]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	209.620	49.920	338.800	23.140	
G2	209.400	61.230	349.590	23.130	

[TORSION MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	0.820	9.480	569.870	0.009	
G2	-1.000	9.530	345.430	0.008	

[5경간 정모멘트부]

[BENDING MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	5,503.290	1,371.040	5,700.450	436.111	-0.09
G2	5,498.380	1,579.670	6,288.920	435.932	-0.09

[SHEAR FORCE]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	3.090	-0.180	345.470	48.801	
G2	3.000	6.710	631.710	48.781	

[TORSION MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-0.160	1.690	540.330	0.026	
G2	0.100	1.770	312.400	0.024	

[6경간 정모멘트부]

[BENDING MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	5,503.290	1,371.040	5,700.450	436.111	-0.09
G2	5,498.380	1,579.670	6,288.920	435.932	-0.09

[SHEAR FORCE]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	3.090	-0.180	345.470	48.801	
G2	3.000	6.710	361.710	48.781	

[TORSION MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	0.160	-1.690	535.750	0.026	
G2	-0.100	-1.770	305.160	0.024	

[7경간 정모멘트부]

[BENDING MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	12,882.160	3,188.440	7,179.830	568.093	0.53
G2	12,873.070	3,485.380	7,940.110	567.856	0.53

[SHEAR FORCE]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	209.620	49.920	338.800	23.140	
G2	209.400	61.230	349.590	23.130	

[TORSION MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-0.820	-9.480	545.700	0.009	
G2	1.000	-9.530	-334.710	0.008	

[4경간 부모멘트부]

[BENDING MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-20,278.140	-4,923.770	-7,803.640	-1,262.657	-0.3
G2	-20,260.380	-5,676.430	-9,572.830	-1,262.125	-0.3

[SHEAR FORCE]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-1,764.560	-412.210	-846.570	-48.822	
G2	-1,762.800	-497.160	-1,004.280	-48.801	

[TORSION MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-0.250	-35.110	-931.240	-0.038	
G2	0.020	-36.820	-795.540	-0.038	

[5경간 부모멘트부]

[BENDING MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-12,613.500	-3,067.250	-6,676.970	-1,422.439	0.16
G2	-12,600.680	-3,682.950	-8,175.210	-1,421.835	0.16

[SHEAR FORCE]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	1,160.240	278.040	723.210	-48.760	
G2	1,159.020	338.350	873.250	-48.739	

[TORSION MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-0.240	-19.590	-870.100	-0.126	
G2	-0.200	-21.400	-721.710	-0.128	

[6경간 부모멘트부]

[BENDING MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-20,278.140	-4,923.770	-7,803.640	-1,262.657	-0.3
G2	-20,260.380	-5,676.430	-9,572.820	-1,262.125	-0.3

[SHEAR FORCE]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-1,764.560	-412.210	-846.570	-48.822	
G2	-1,762.800	-497.160	-1,004.280	-48.801	

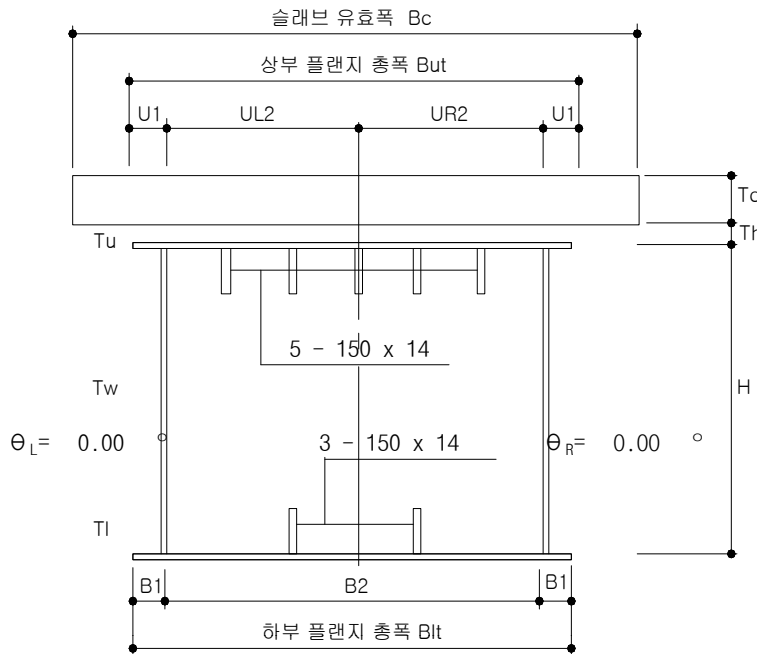
[TORSION MOMENT]

거더 번호	합성전 고정하중	합성후 고정하중	활하중	지점침하	비 고
G1	-0.350	-11.290	-898.300	-0.038	
G2	-0.430	-13.180	-763.900	-0.038	

5. 단면검토

5-1. 4경간 최대 정모멘트 단면검토(G1)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.700 m

Bc = 6.052 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 = 0.200 m

Th = 0.100 m

Tu = 0.016 m

TI = 0.020 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	℃	10
Ms : 합성전 고정하중에 의한 모멘트	kN · m	12882.160
Msc : 합성후 고정하중에 의한 모멘트	kN · m	3188.440
Mv : 활하중+지점침하에 의한 모멘트	kN · m	7747.923
Ss : 합성전 고정하중에 의한 전단력	kN	209.620
Ssc : 합성후 고정하중에 의한 전단력	kN	49.920
Sv : 활하중+지점침하에 의한 전단력	kN	361.940
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	0.820
Msct : 합성후 고정하중에 의한 비틀림모멘트	kN · m	9.480
Mvt : 활하중+지점침하에 의한 비틀림모멘트	kN · m	569.879

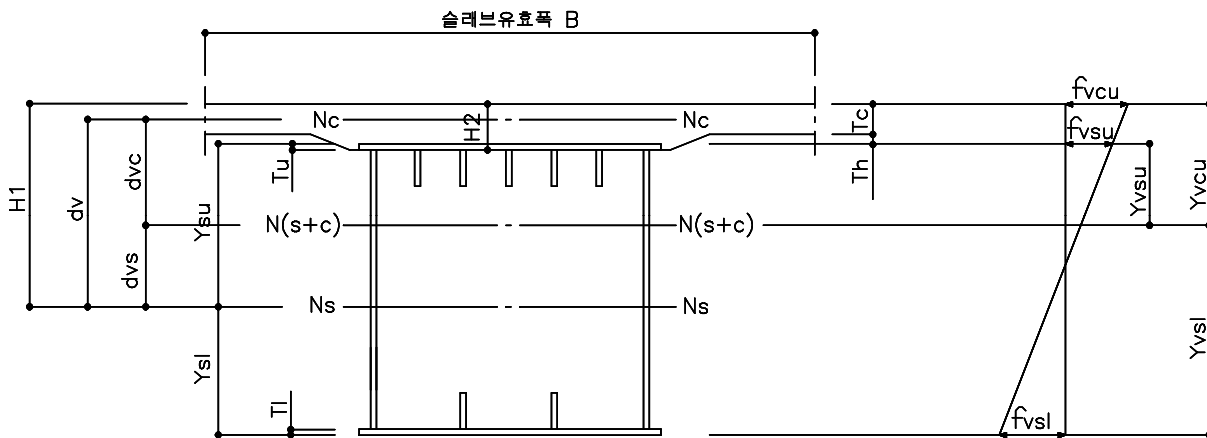
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	1358.0	58665600	79667884800	921600
5 - UPPER RIB	14.0	150.0	10500	1275.0	13387500	17069062500	19687500
1 - L_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
3 - LOWER RIB	14.0	150.0	6300	-1275.0	-8032500	10241437500	11812500
1 - LOWER FLANGE	2700.0	20.0	54000	-1360.0	-73440000	99878400000	1800000
강단면 합계			178800		-9419400	2.06857E+11	39400221600
1 - RC SLAB	6052.0	200.0	1210400	1550.0	1876120000	2907986000000	4034666667

* As = 178800 mm² , Ac = 1210400 mm²

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = \text{#####} + 39400221600.0 = 246257006400 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -9419400 / 178800 = -52.681 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = \text{#####} - 178800 \times (-52.681)^2 = 245760781029 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2700.0 / 2 + 16.0 - (-52.681) = 1418.681 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1418.681 - 2736.000 = -1317.319 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + T_u/2 + T_l/2) = 6827616.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 74.364 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = -69.051 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 3.240 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 330100.0 \text{ mm}^2$$

$$I_c/n = 504333333 \text{ mm}^4$$

$$I_{cn} = 1000000000000 \text{ mm}^4$$

$$868.1$$

$$\begin{aligned}
dvs &= dv - dvc = 734.6 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 968.1 \text{ mm} \\
Yvcl &= Yvcu - Tc = 768.1 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 684.1 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2051.9 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 456766620514 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6859016.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.845 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.670 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 4.775 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -14.323 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.828 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 2.053 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.629 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 11.604 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -34.805 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 9.047 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 254450.0 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1126.2 \text{ mm} & K = 0.530 \\
ds1 &= dv - dc1 = 476.5 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1226.2 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 1026.2 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 942.2 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1793.8 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 382555583146 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 916837 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 916837 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 1032533513 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.845 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.670 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.510 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.353 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 4.951 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = -14.323 \text{ MPa}
\end{aligned}$$

(5) 건조수축

$$n2 = n \cdot (1 + \phi2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 229233.333 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1250.1 \text{ mm}$$

$$ds2 = dv - dc2 = 352.6 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1350.1 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1150.1 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 1066.1 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1669.9 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 346970839472.6 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon s \cdot Ac/n2 = 1906380 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2383122476 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon s = -1.024 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon s = -1.054 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 12.197 \text{ MPa}$$

$$fvsl2 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 2.237 \text{ MPa}$$

(6) 온도차

$$\epsilon t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon t \cdot Ac/n = 3812760 \text{ N}$$

$$Mvt = P1 \cdot dvc = 3309852220 \text{ N} \cdot \text{mm}$$

$$fcut = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon t = -1.296 \text{ MPa}$$

$$fclt = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon t = -1.392 \text{ MPa}$$

$$fsut = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 14.178 \text{ MPa}$$

$$fslt = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 3.670 \text{ MPa}$$

(7) 전단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 13.115 \text{ MPa} < ua = 110 \text{ MPa} \quad \text{O.K.}$$

(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	74.364	-69.051	182.038	190.000
1+2+3	2.897	2.299	10.800	10.800	90.743	-118.179	182.038	190.000
1+2+3+4	2.388	1.946	10.800	10.800	95.694	-117.142	209.344	190.000
1+2+3+4+5	1.364	0.892	10.800	10.800	107.891	-114.905	209.344	190.000
1+2+3+4+5+6	0.068	-0.500	12.420	2.174	122.069	-111.235	236.649	218.500
1+2+3+4+5-6	2.659	2.283	12.420	12.420	93.714	-118.575	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)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{122.069}{236.649} \right)^2 + \left(\frac{13.115}{110.000} \right)^2$$

$$= 0.266 + 0.014 = 0.280 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-118.179}{190.000} \right)^2 + \left(\frac{13.115}{110.000} \right)^2$$

$$= 0.377 + 0.014 = 0.391 < 1.2 \quad \mathbf{O.K.}$$

(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)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 20 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 20 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/74.364)} = 1.598 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 5.2 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/122.069)} = 1.248 > 1.2 \Rightarrow 1.200$$

(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

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.845 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 2.897 - 0.845 = 2.053 \text{ MPa}$$

$$\Sigma f = 1.3 \times 0.845 + 2.15 \times 2.053 + (-0.51) + (-1.024) + (1.296) \\ = 5.273 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times 0.845 + 2.15 \times 2.053 + (1.296) \\ = 6.807 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 74.364 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 4.775 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 90.743 - 74.364 - 4.775 = 11.604 \text{ MPa}$$

$$\Sigma f = 1.3 \times (74.364 + 4.775) + 2.15 \times 11.604 + (4.951) + (12.197) + (14.178) \\ = 159.155 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (74.364 + 4.775) + 2.15 \times 11.604 + (14.178) \\ = 142.007 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -69.051 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -14.323 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -118.179 - (-69.051) - (-14.323) = -34.805 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-69.051 + -14.323) + 2.15 \times -34.805 + (1.037) + (2.237) + (-3.67) \\ = -183.613 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (-69.051 + -14.323) + 2.15 \times -34.805 + (-3.67) \\ = -186.887 \text{ MPa} < 315.0$$

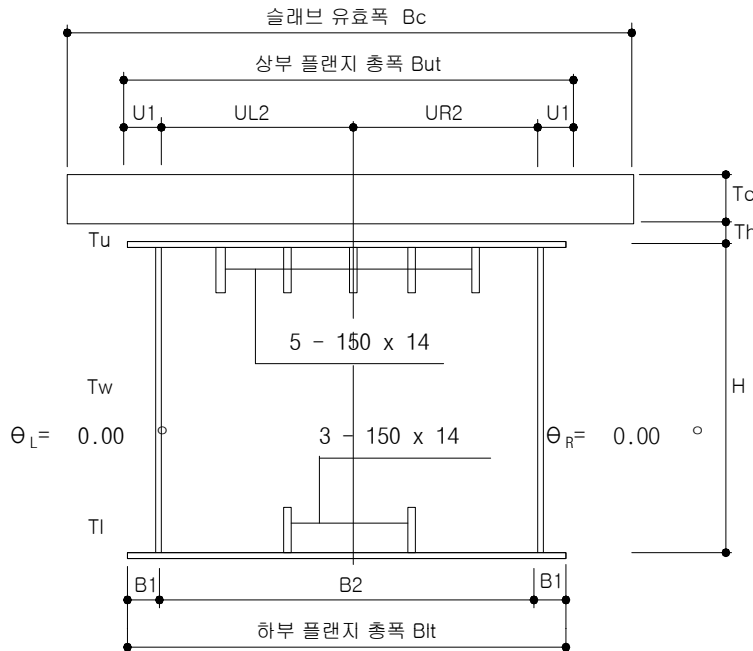
- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	5.273	16.200	0.K!!!	3.07
	크리프, 건조수축제외시	6.807	16.200	0.K!!!	2.37
상부플랜지	크리프, 건조수축 포함시	159.155	315.000	0.K!!!	1.97
	크리프, 건조수축제외시	142.007	315.000	0.K!!!	2.21
하부플랜지	크리프, 건조수축 포함시	-183.613	315.000	0.K!!!	1.71
	크리프, 건조수축제외시	-186.887	315.000	0.K!!!	1.68

5-2. 5경간 최대 정모멘트 단면검토(G1)

1) 단면가정 및 설계조건

주부재사용강종 = SM490


$$H = 2.700 \text{ m}$$
$$B_C = 5.961 \text{ m}$$

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

$$T_C = 0.200 \text{ m}$$
$$T_h = 0.100 \text{ m}$$
$$T_u = 0.012 \text{ m}$$
$$Tl = 0.014 \text{ m}$$
$$T_W = 0.012 \text{ m}$$
$$U1 = 0.100 \text{ m}$$
$$B1 = 0.100 \text{ m}$$

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 선팅창계수		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	5503.290
M_{sc} : 합성후 고정하중에 의한 모멘트	kN · m	1371.040
M_v : 활하중+지점침하에 의한 모멘트	kN · m	6136.561
S_s : 합성전 고정하중에 의한 전단력	kN	3.090
S_{sc} : 합성후 고정하중에 의한 전단력	kN	-0.180
S_v : 활하중+지점침하에 의한 전단력	kN	394.271
M_{st} : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-0.160
M_{sct} : 합성후 고정하중에 의한 비틀림모멘트	kN · m	1.690
M_{vt} : 활하중+지점침하에 의한 비틀림모멘트	kN · m	540.356

< 참고 > 합성전 고정하중 : 강재자중 + 바닥판콘크리트자중

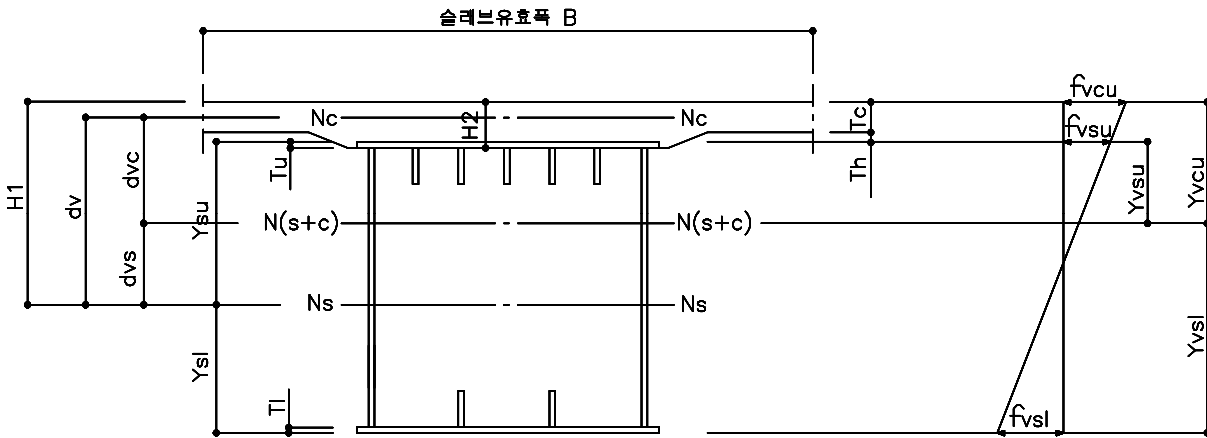
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	12.0	32400	1356.0	43934400	59575046400	388800
5 - UPPER RIB	14.0	150.0	10500	1275.0	13387500	17069062500	19687500
1 - L_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
3 - LOWER RIB	14.0	150.0	6300	-1275.0	-8032500	10241437500	11812500
1 - LOWER FLANGE	2700.0	14.0	37800	-1357.0	-51294600	69606772200	617400
강단면 합계			151800		-2005200	1.56492E+11	39398506200
1 - RC SLAB	5961.0	200.0	1192200	1550.0	1847910000	2864260500000	3974000000

$$* A_s = 151800 \text{ mm}^2, A_c = 1192200 \text{ mm}^2$$

2) 응력 검토



(1) 합성 전

$$I_s' = A_s \cdot Y_2 + \sum I_s = ##### + 39398506200.0 = 195890824800 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = \frac{-2005200}{151800} = -13.209 \text{ mm}$$

$$I_s = I_{s'} - A_s \cdot \delta s^2 = \text{#####} - 151800 \times -13.209^2 = 195864337138 \text{ nm}^4$$

$$Y_{su} = H/2 + T_u - \delta_s = 2700.0 / 2 + 12.0 - -13.209 = 1375.209 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1375.209 - 2726.000 = -1350.791 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6815056.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 38.640 \text{ MPa}$$

$$f_{sI} = M_s \cdot Y_{sI} / I_s = -37.954 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot T_w) = 0.049 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 300825.0 \text{ mm}^2$$

$$I_{c/n} = 496750000 \text{ nm}^4$$

1000 700 600 500 400 300 200 100 0

788.8

$$\begin{aligned}
dvs &= dv - dvc = 774.4 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 888.8 \text{ mm} \\
Yvcl &= Yvcu - Tc = 688.8 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 600.8 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2125.2 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 380121238702 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6846456.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.401 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.311 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 2.167 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -7.665 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.013 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 1.794 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.390 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 9.699 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -34.308 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 9.373 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 226312.5 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1048.5 \text{ mm} & K = -0.090 \\
ds1 &= dv - dc1 = 514.7 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1148.5 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 948.5 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 860.5 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1865.5 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 318243941289 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 423996 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 423996 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 444572464 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.401 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.311 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.293 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.201 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 1.765 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = 0.400 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 201475.000 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1177.8 \text{ mm}$$

$$ds2 = dv - dc2 = 385.4 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1277.8 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1077.8 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 989.8 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1736.2 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 287488161931.4 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 1877715 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2211553575 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon_s = -1.224 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon_s = -1.218 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 8.635 \text{ MPa}$$

$$fvsl2 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 10.522 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 3755430 \text{ N}$$

$$Mvt = P1 \cdot dvc = 2962338612 \text{ N} \cdot \text{mm}$$

$$fcut1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon_t = -1.722 \text{ MPa}$$

$$fclt1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon_t = -1.704 \text{ MPa}$$

$$fsut1 = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 12.062 \text{ MPa}$$

$$fslt1 = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 13.974 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 9.427 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(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	38.640	-37.954	148.183	190.000
1+2+3	2.194	1.701	10.800	10.800	50.506	-79.927	148.183	190.000
1+2+3+4	1.902	1.500	10.800	10.800	52.272	-77.819	170.410	190.000
1+2+3+4+5	0.678	0.282	10.800	10.800	60.906	-67.297	170.410	190.000
1+2+3+4+5+6	-1.044	-1.422	2.174	2.174	72.969	-53.323	192.638	218.500
1+2+3+4+5-6	2.400	1.986	12.420	12.420	48.844	-81.272	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)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{72.969}{192.638} \right)^2 + \left(\frac{9.427}{110.000} \right)^2$$

$$= 0.143 + 0.007 = 0.151 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-79.927}{190.000} \right)^2 + \left(\frac{9.427}{110.000} \right)^2$$

$$= 0.173 + 0.007 = 0.180 < 1.2 \quad \mathbf{O.K.}$$

(10) 판의 최소두께 검토

압축(상부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = 10 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K. (합성형 스퍼드 설치)}$$

인장(하부)플랜지 (☞ 도.설.기 3.8.3.1 및 3.8.3.2)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/38.64)} = 2.217 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 4.6 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/72.969)} = 1.614 > 1.2 \Rightarrow 1.200$$

(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

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.401 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 2.194 - 0.401 = 1.794 \text{ MPa}$$

$$\Sigma f = 1.3 \times 0.401 + 2.15 \times 1.794 + (-0.293) + (-1.224) + (1.722) \\ = 4.583 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times 0.401 + 2.15 \times 1.794 + (1.722) \\ = 6.099 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 38.640 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 2.167 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 50.506 - 38.64 - 2.167 = 9.699 \text{ MPa}$$

$$\Sigma f = 1.3 \times (38.64 + 2.167) + 2.15 \times 9.699 + (1.765) + (8.635) + (12.062) \\ = 96.365 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (38.64 + 2.167) + 2.15 \times 9.699 + (12.062) \\ = 85.965 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -37.954 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -7.665 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -79.927 - (-37.954) - (-7.665) = -34.308 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-37.954 + -7.665) + 2.15 \times -34.308 + (2.108) + (10.522) + (-13.974) \\ = -134.412 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (-37.954 + -7.665) + 2.15 \times -34.308 + (-13.974) \\ = -147.042 \text{ MPa} < f_y = 315.0 \text{ MPa}$$

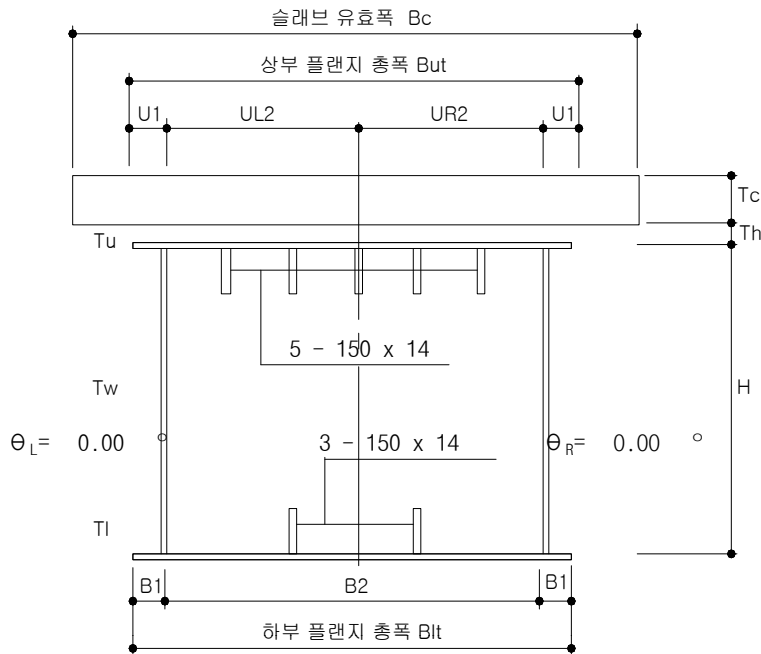
- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	4.583	16.200	0.K!!!	3.53
	크리프, 건조수축제외시	6.099	16.200	0.K!!!	2.65
상부플랜지	크리프, 건조수축 포함시	96.365	315.000	0.K!!!	3.26
	크리프, 건조수축제외시	85.965	315.000	0.K!!!	3.66
하부플랜지	크리프, 건조수축 포함시	-134.412	315.000	0.K!!!	2.34
	크리프, 건조수축제외시	-147.042	315.000	0.K!!!	2.14

5-3. 6경간 최대 정모멘트 단면검토(G1)

1) 단면가정 및 설계조건

주부재사용강종 = SM490


$$H = 2.700 \text{ m}$$
$$B_C = 5.961 \text{ m}$$

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

$$T_C = 0.200 \text{ m}$$
$$T_h = 0.100 \text{ m}$$
$$T_u = 0.012 \text{ m}$$
$$Tl = 0.014 \text{ m}$$
$$T_W = 0.012 \text{ m}$$
$$U1 = 0.100 \text{ m}$$
$$B1 = 0.100 \text{ m}$$

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
ϕ_2 : 건조수축에 의한 크리이프계수		4
n : 강과 콘크리트의 탄성계수비		8
t : 강과 콘크리트의 온도차	℃	10
M_s : 합성전 고정하중에 의한 모멘트	kN · m	5503.290
M_{sc} : 합성후 고정하중에 의한 모멘트	kN · m	1371.040
M_v : 활하중+지점침하에 의한 모멘트	kN · m	6136.561
S_s : 합성전 고정하중에 의한 전단력	kN	3.090
S_{sc} : 합성후 고정하중에 의한 전단력	kN	-0.180
S_v : 활하중+지점침하에 의한 전단력	kN	394.271
M_{st} : 합성전 고정하중에 의한 비틀림모멘트	kN · m	0.160
M_{sct} : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-1.690
M_{vt} : 활하중+지점침하에 의한 비틀림모멘트	kN · m	535.776

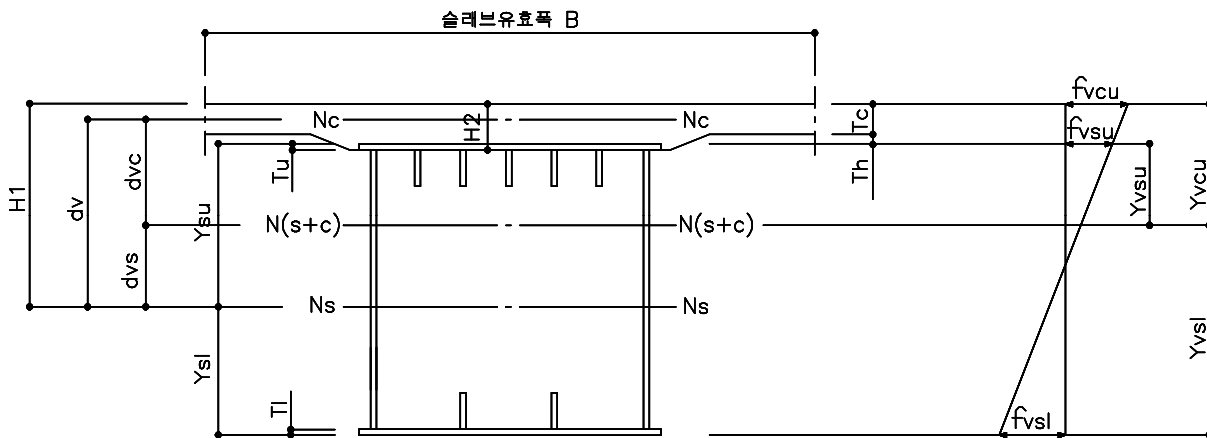
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	12.0	32400	1356.0	43934400	59575046400	388800
5 - UPPER RIB	14.0	150.0	10500	1275.0	13387500	17069062500	19687500
1 - L_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
3 - LOWER RIB	14.0	150.0	6300	-1275.0	-8032500	10241437500	11812500
1 - LOWER FLANGE	2700.0	14.0	37800	-1357.0	-51294600	69606772200	617400
강단면 합계			151800		-2005200	1.56492E+11	39398506200
1 - RC SLAB	5961.0	200.0	1192200	1550.0	1847910000	2864260500000	3974000000

* As = 151800 mm² , Ac = 1192200 mm²

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = ##### + 39398506200.0 = 195890824800 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -2005200 / 151800 = -13.209 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = ##### - 151800 \times (-13.209)^2 = 195864337138 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2700.0 / 2 + 12.0 - (-13.209) = 1375.209 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1375.209 - 2726.000 = -1350.791 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + T_u/2 + T_l/2) = 6815056.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 38.640 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = -37.954 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 0.049 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 300825.0 \text{ mm}^2$$

$$I_c/n = 496750000 \text{ mm}^4$$

$$I_{cs} = I_c/n + A_v \cdot Y_{cs}^2 = 496750000 + 300825.0 \cdot 1550.0^2 = 718110000000 \text{ mm}^4$$

$$I_{cs} = 718110000000 \text{ mm}^4$$

$$\begin{aligned}
dvs &= dv - dvc = 774.4 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 888.8 \text{ mm} \\
Yvcl &= Yvcu - Tc = 688.8 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 600.8 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2125.2 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 380121238702 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6846456.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.401 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.311 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 2.167 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -7.665 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.013 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 1.794 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.390 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 9.699 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -34.308 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 9.345 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 226312.5 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1048.5 \text{ mm} & K = -0.090 \\
ds1 &= dv - dc1 = 514.7 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1148.5 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 948.5 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 860.5 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1865.5 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 318243941289 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 423996 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 423996 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 444572464 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.401 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.311 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.293 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.201 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 1.765 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = -1.422 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 201475.000 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1177.8 \text{ mm}$$

$$ds2 = dv - dc2 = 385.4 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1277.8 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1077.8 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 989.8 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1736.2 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 287488161931.4 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 1877715 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2211553575 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon_s = -1.224 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon_s = -1.218 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 8.635 \text{ MPa}$$

$$fvsl2 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 10.522 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 3755430 \text{ N}$$

$$Mvt = P1 \cdot dvc = 2962338612 \text{ N} \cdot \text{mm}$$

$$fcut = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon_t = -1.722 \text{ MPa}$$

$$fclt = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon_t = -1.704 \text{ MPa}$$

$$fsut = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 12.062 \text{ MPa}$$

$$fslt = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 13.974 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 9.381 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(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	38.640	-37.954	148.183	190.000
1+2+3	2.194	1.701	10.800	10.800	50.506	-79.927	148.183	190.000
1+2+3+4	1.902	1.500	10.800	10.800	52.272	-77.819	170.410	190.000
1+2+3+4+5	0.678	0.282	10.800	10.800	60.906	-67.297	170.410	190.000
1+2+3+4+5+6	-1.044	-1.422	2.174	2.174	72.969	-53.323	192.638	218.500
1+2+3+4+5-6	2.400	1.986	12.420	12.420	48.844	-81.272	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)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{72.969}{192.638} \right)^2 + \left(\frac{9.381}{110.000} \right)^2$$

$$= 0.143 + 0.007 = 0.151 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-79.927}{190.000} \right)^2 + \left(\frac{9.381}{110.000} \right)^2$$

$$= 0.173 + 0.007 = 0.180 < 1.2 \quad \mathbf{O.K.}$$

(10) 판의 최소두께 검토

압축(상부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = 10 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K. (합성형 스퍼드 설치)}$$

인장(하부)플랜지 (☞ 도.설.기 3.8.3.1 및 3.8.3.2)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/38.64)} = 2.217 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 4.6 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/72.969)} = 1.614 > 1.2 \Rightarrow 1.200$$

(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

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.401 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 2.194 - 0.401 = 1.794 \text{ MPa}$$

$$\Sigma f = 1.3 \times 0.401 + 2.15 \times 1.794 + (-0.293) + (-1.224) + (1.722) \\ = 4.583 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times 0.401 + 2.15 \times 1.794 + (1.722) \\ = 6.099 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 38.640 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 2.167 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 50.506 - 38.64 - 2.167 = 9.699 \text{ MPa}$$

$$\Sigma f = 1.3 \times (38.64 + 2.167) + 2.15 \times 9.699 + (1.765) + (8.635) + (12.062) \\ = 96.365 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (38.64 + 2.167) + 2.15 \times 9.699 + (12.062) \\ = 85.965 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -37.954 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -7.665 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -79.927 - (-37.954) - (-7.665) = -34.308 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-37.954 + -7.665) + 2.15 \times -34.308 + (2.108) + (10.522) + (-13.974) \\ = -134.412 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

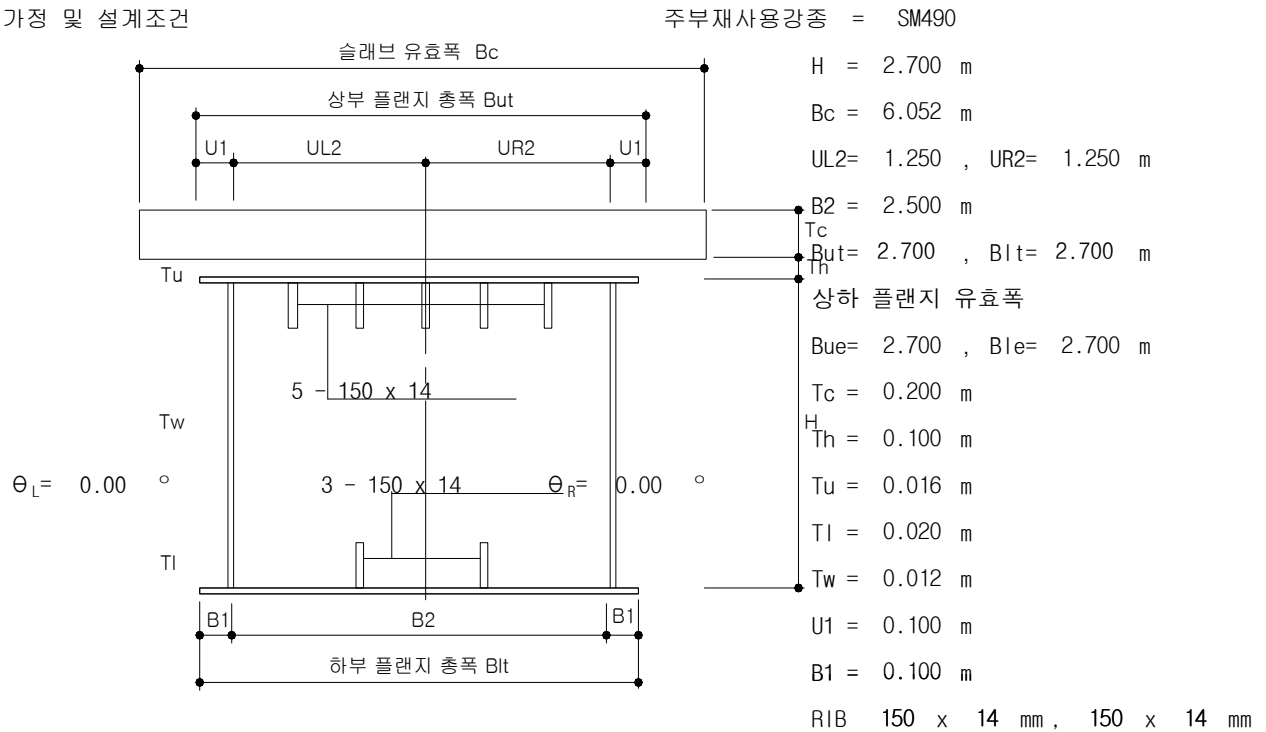
$$\Sigma f = 1.3 \times (-37.954 + -7.665) + 2.15 \times -34.308 + (-13.974) \\ = -147.042 \text{ MPa} < f_y = 315.0 \text{ MPa}$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	4.583	16.200	0.K!!!	3.53
	크리프, 건조수축제외시	6.099	16.200	0.K!!!	2.65
상부플랜지	크리프, 건조수축 포함시	96.365	315.000	0.K!!!	3.26
	크리프, 건조수축제외시	85.965	315.000	0.K!!!	3.66
하부플랜지	크리프, 건조수축 포함시	-134.412	315.000	0.K!!!	2.34
	크리프, 건조수축제외시	-147.042	315.000	0.K!!!	2.14

5-4. 7경간 최대 정모멘트 단면검토(G1)

1) 단면가정 및 설계조건



구 분	단 위	입력 DATA
Es : 강 의 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	℃	10
Ms : 합성전 고정하중에 의한 모멘트	kN · m	12882.160
Msc : 합성후 고정하중에 의한 모멘트	kN · m	3188.440
Mv : 활하중+지점침하에 의한 모멘트	kN · m	7747.923
Ss : 합성전 고정하중에 의한 전단력	kN	209.620
Ssc : 합성후 고정하중에 의한 전단력	kN	49.920
Sv : 활하중+지점침하에 의한 전단력	kN	361.940
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-0.820
Mstc : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-9.480
Mvt : 활하중+지점침하에 의한 비틀림모멘트	kN · m	545.709

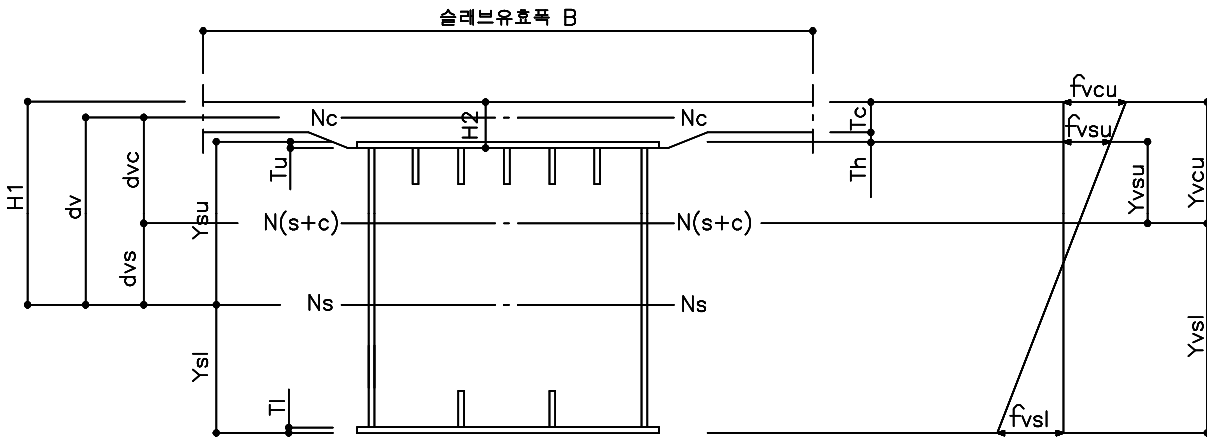
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	1358.0	58665600	79667884800	921600
5 - UPPER RIB	14.0	150.0	10500	1275.0	13387500	17069062500	19687500
1 - L_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
3 - LOWER RIB	14.0	150.0	6300	-1275.0	-8032500	10241437500	11812500
1 - LOWER FLANGE	2700.0	20.0	54000	-1360.0	-73440000	99878400000	1800000
강단면 합계			178800		-9419400	2.06857E+11	39400221600
1 - RC SLAB	6052.0	200.0	1210400	1550.0	1876120000	2907986000000	4034666667

$$* A_s = 178800 \text{ mm}^2, A_c = 1210400 \text{ mm}^2$$

2) 응력 검토



(1) 합성 전

$$I_s' = A_s \cdot Y_2 + \sum I_s = \text{#####} + 39400221600.0 = 246257006400 \text{ nm}^4$$

$$\delta_s = \sum (A \cdot Y) / A_s = \frac{-9419400}{178800} = -52.681 \text{ mm}$$

$$I_s = I_{s'} - A_s \cdot \delta s^2 = \text{#####} - 178800 \times -52.681^2 = 245760781029 \text{ nm}^4$$

$$Y_{su} = H/2 + T_u - \delta_s = 2700.0 / 2 + 16.0 - -52.681 = 1418.681 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1418.681 - 2736.000 = -1317.319 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6827616.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 74.364 \text{ MPa}$$

$$f_{sI} = M_s \cdot Y_{sI} / I_s = -69.051 \text{ MPa}$$

$$U = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot T_w) = 3.240 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 330100.0 \text{ mm}^2$$

$$I_{c/n} = 50433333 \text{ nm}^4$$

1000 7

868.1

$$\begin{aligned}
dvs &= dv - dvc = 734.6 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 968.1 \text{ mm} \\
Yvcl &= Yvcu - Tc = 768.1 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 684.1 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2051.9 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 456766620514 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6859016.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.845 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.670 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 4.775 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -14.323 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.828 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 2.053 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.629 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 11.604 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -34.805 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 8.901 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 254450.0 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1126.2 \text{ mm} & K = 0.530 \\
ds1 &= dv - dc1 = 476.5 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1226.2 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 1026.2 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 942.2 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1793.8 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 382555583146 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 916837 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 916837 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 1032533513 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.845 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.670 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.510 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.353 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 4.951 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = 4.887 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 229233.333 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1250.1 \text{ mm}$$

$$ds2 = dv - dc2 = 352.6 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1350.1 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1150.1 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 1066.1 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1669.9 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 346970839472.6 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 1906380 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2383122476 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon_s = -1.024 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon_s = -1.054 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 12.197 \text{ MPa}$$

$$fvs12 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 2.237 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 3812760 \text{ N}$$

$$Mvt = P1 \cdot dvc = 3309852220 \text{ N} \cdot \text{mm}$$

$$fcut1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon_t = -1.296 \text{ MPa}$$

$$fclt1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon_t = -1.392 \text{ MPa}$$

$$fsut1 = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 14.178 \text{ MPa}$$

$$fslt1 = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 3.670 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 12.843 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(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	74.364	-69.051	182.038	190.000
1+2+3	2.897	2.299	10.800	10.800	90.743	-118.179	182.038	190.000
1+2+3+4	2.388	1.946	10.800	10.800	95.694	-117.142	209.344	190.000
1+2+3+4+5	1.364	0.892	10.800	10.800	107.891	-114.905	209.344	190.000
1+2+3+4+5+6	0.068	-0.500	12.420	2.174	122.069	-111.235	236.649	218.500
1+2+3+4+5-6	2.659	2.283	12.420	12.420	93.714	-118.575	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)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{122.069}{236.649} \right)^2 + \left(\frac{12.843}{110.000} \right)^2$$

$$= 0.266 + 0.014 = 0.280 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-118.179}{190.000} \right)^2 + \left(\frac{12.843}{110.000} \right)^2$$

$$= 0.377 + 0.014 = 0.391 < 1.2 \quad \mathbf{O.K.}$$

(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)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 20 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 20 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/74.364)} = 1.598 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 5.2 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/122.069)} = 1.248 > 1.2 \Rightarrow 1.200$$

(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

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.845 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 2.897 - 0.845 = 2.053 \text{ MPa}$$

$$\begin{aligned} \Sigma f &= 1.3 \times 0.845 + 2.15 \times 2.053 + (-0.51) + (-1.024) + (1.296) \\ &= 5.273 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)} \end{aligned}$$

$$\begin{aligned} \Sigma f &= 1.3 \times 0.845 + 2.15 \times 2.053 + (1.296) \\ &= 6.807 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)} \end{aligned}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 74.364 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 4.775 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 90.743 - 74.364 - 4.775 = 11.604 \text{ MPa}$$

$$\begin{aligned} \Sigma f &= 1.3 \times (74.364 + 4.775) + 2.15 \times 11.604 + (4.951) + (12.197) + (14.178) \\ &= 159.155 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)} \end{aligned}$$

$$\begin{aligned} \Sigma f &= 1.3 \times (74.364 + 4.775) + 2.15 \times 11.604 + (14.178) \\ &= 142.007 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)} \end{aligned}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -69.051 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -14.323 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -118.179 - (-69.051) - (-14.323) = -34.805 \text{ MPa}$$

$$\begin{aligned} \Sigma f &= 1.3 \times (-69.051 + -14.323) + 2.15 \times -34.805 + (1.037) + (2.237) + (-3.67) \\ &= -183.613 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)} \end{aligned}$$

$$\begin{aligned} \Sigma f &= 1.3 \times (-69.051 + -14.323) + 2.15 \times -34.805 + (-3.67) \\ &= -186.887 \text{ MPa} < f_y = 315.0 \text{ MPa} \end{aligned}$$

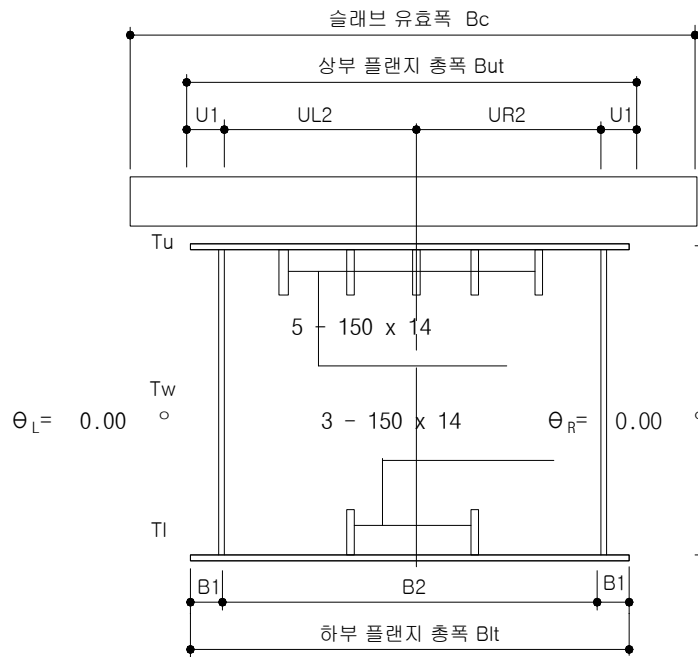
- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	5.273	16.200	0.K!!!	3.07
	크리프, 건조수축제외시	6.807	16.200	0.K!!!	2.37
상부플랜지	크리프, 건조수축 포함시	159.155	315.000	0.K!!!	1.97
	크리프, 건조수축제외시	142.007	315.000	0.K!!!	2.21
하부플랜지	크리프, 건조수축 포함시	-183.613	315.000	0.K!!!	1.71
	크리프, 건조수축제외시	-186.887	315.000	0.K!!!	1.68

5-5. 4경간 최대 정모멘트 단면검토(G2)

1) 단면가정 및 설계조건

주부재사용강종 = SM490


$$H = 2.700 \text{ m}$$
$$B_c = 6.042 \text{ m}$$

UL2= 1.250 , UR2= 1.250 m

$$B2 = 2.500 \text{ m}$$
$$T_{CBut} = 2.700, \quad BIt = 2.700 \text{ m}$$

가상하 플랜지 유효폭

Bue= 2.700 , Ble= 2.700 m

$$T_C = 0.200 \text{ m}$$
$$|_{\text{Th}} = 0.100 \text{ m}$$
$$T_u = 0.016 \text{ m}$$
$$Tl = 0.020 \text{ m}$$
$$T_W = 0.012 \text{ m}$$
$$U1 = 0.100 \text{ m}$$
$$B1 = 0.100 \text{ m}$$

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 선팅창계수		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	12873.070
M_{sc} : 합성후 고정하중에 의한 모멘트	kN · m	3485.380
M_v : 활하중+지점침하에 의한 모멘트	kN · m	8507.966
S_s : 합성전 고정하중에 의한 전단력	kN	209.400
S_{sc} : 합성후 고정하중에 의한 전단력	kN	61.230
S_v : 활하중+지점침하에 의한 전단력	kN	372.720
M_{st} : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-1.000
M_{sct} : 합성후 고정하중에 의한 비틀림모멘트	kN · m	9.530
M_{vt} : 활하중+지점침하에 의한 비틀림모멘트	kN · m	345.438

< 참고 > 합성전 고정하중 : 강재자중 + 바닥판콘크리트자중

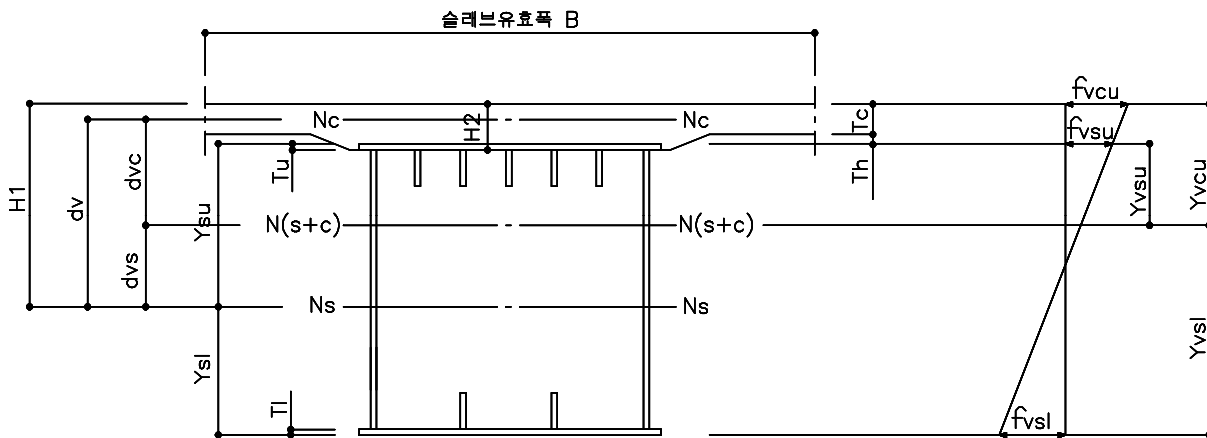
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	1358.0	58665600	79667884800	921600
5 - UPPER RIB	14.0	150.0	10500	1275.0	13387500	17069062500	19687500
1 - L_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
3 - LOWER RIB	14.0	150.0	6300	-1275.0	-8032500	10241437500	11812500
1 - LOWER FLANGE	2700.0	20.0	54000	-1360.0	-73440000	99878400000	1800000
강단면 합계			178800		-9419400	2.06857E+11	39400221600
1 - RC SLAB	6042.0	200.0	1208400	1550.0	1873020000	2903181000000	4028000000

* As = 178800 mm² , Ac = 1208400 mm²

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = \text{#####} + 39400221600.0 = 246257006400 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -9419400 / 178800 = -52.681 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = \text{#####} - 178800 \times -52.681^2 = 245760781029 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2700.0 / 2 + 16.0 - -52.681 = 1418.681 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1418.681 - 2736.000 = -1317.319 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6827616.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 74.311 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = -69.002 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 3.238 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 329850.0 \text{ mm}^2$$

$$I_c/n = 503500000 \text{ mm}^4$$

$$I_{cs} = I_c/n + A_v \cdot Y_{su}^2 = 1000000000 \text{ mm}^4$$

$$868.8$$

$$\begin{aligned}
dvs &= dv - dvc = 733.9 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 968.8 \text{ mm} \\
Yvcl &= Yvcu - Tc = 768.8 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 684.8 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2051.2 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 456577245526 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6859016.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.924 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.734 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 5.227 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -15.659 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 1.003 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 2.257 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.791 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 12.760 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -38.223 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 7.850 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 254325.0 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1126.7 \text{ mm} & K = 0.530 \\
ds1 &= dv - dc1 = 475.9 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1226.7 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 1026.7 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 942.7 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1793.3 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 382396550176 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 1001739 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 1001739 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 1128704814 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.924 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.734 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.558 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.387 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 5.414 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = 4.400 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 229150.000 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1250.5 \text{ mm}$$

$$ds2 = dv - dc2 = 352.1 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1350.5 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1150.5 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 1066.5 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1669.5 \text{ mm}$$

$$lv2 = ls + lc/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 346840289886.7 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 1903230 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2380049954 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/lv2) - Ec2 \cdot \epsilon_s = -1.024 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/lv2) - Ec2 \cdot \epsilon_s = -1.055 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/lv2 = 12.184 \text{ MPa}$$

$$fvsl2 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/lv2 = 2.234 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 3806460 \text{ N}$$

$$Mvt = P1 \cdot dvc = 3306887657 \text{ N} \cdot \text{mm}$$

$$fcut = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/lv) - Ec \cdot \epsilon_t = -1.297 \text{ MPa}$$

$$fclt = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/lv) - Ec \cdot \epsilon_t = -1.393 \text{ MPa}$$

$$fsut = P1/Av + k \cdot Mvt \cdot Yvsu/lv = 14.169 \text{ MPa}$$

$$fslt = P1/Av + k \cdot Mvt \cdot Yvsl/lv = 3.666 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 12.078 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(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	74.311	-69.002	182.038	190.000
1+2+3	3.181	2.524	10.800	10.800	92.298	-122.884	182.038	190.000
1+2+3+4	2.623	2.137	10.800	10.800	97.712	-121.750	209.344	190.000
1+2+3+4+5	1.598	1.083	10.800	10.800	109.896	-119.516	209.344	190.000
1+2+3+4+5+6	0.301	-0.310	12.420	2.174	124.065	-115.850	236.649	218.500
1+2+3+4+5-6	2.895	2.475	12.420	12.420	95.728	-123.182	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)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{109.896}{209.344} \right)^2 + \left(\frac{12.078}{110.000} \right)^2$$

$$= 0.276 + 0.012 = 0.288 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-122.884}{190.000} \right)^2 + \left(\frac{12.078}{110.000} \right)^2$$

$$= 0.412 + 0.012 = 0.424 < 1.2 \quad \mathbf{O.K.}$$

(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)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 20 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 20 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/74.311)} = 1.599 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 5.2 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(fca/fc)} = \sqrt{(190/124.065)} = 1.238 > 1.2 \Rightarrow 1.200$$

(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

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.924 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 3.181 - 0.924 = 2.257 \text{ MPa}$$

$$\Sigma f = 1.3 \times 0.924 + 2.15 \times 2.257 + (-0.558) + (-1.024) + (1.297) = 5.768 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times 0.924 + 2.15 \times 2.257 + (1.297) = 7.350 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 74.311 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 5.227 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 92.298 - 74.311 - 5.227 = 12.760 \text{ MPa}$$

$$\Sigma f = 1.3 \times (74.311 + 5.227) + 2.15 \times 12.76 + (5.414) + (12.184) + (14.169) = 162.601 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (74.311 + 5.227) + 2.15 \times 12.76 + (14.169) = 145.003 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -69.002 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -15.659 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -122.884 - (-69.002) - (-15.659) = -38.223 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-69.002 + -15.659) + 2.15 \times -38.223 + (1.133) + (2.234) + (-3.666) = -192.537 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (-69.002 + -15.659) + 2.15 \times -38.223 + (-3.666) = -195.904 \text{ MPa} < f_y = 315.0 \text{ MPa}$$

- 항복에 대한 안전도 검사 결과 집계

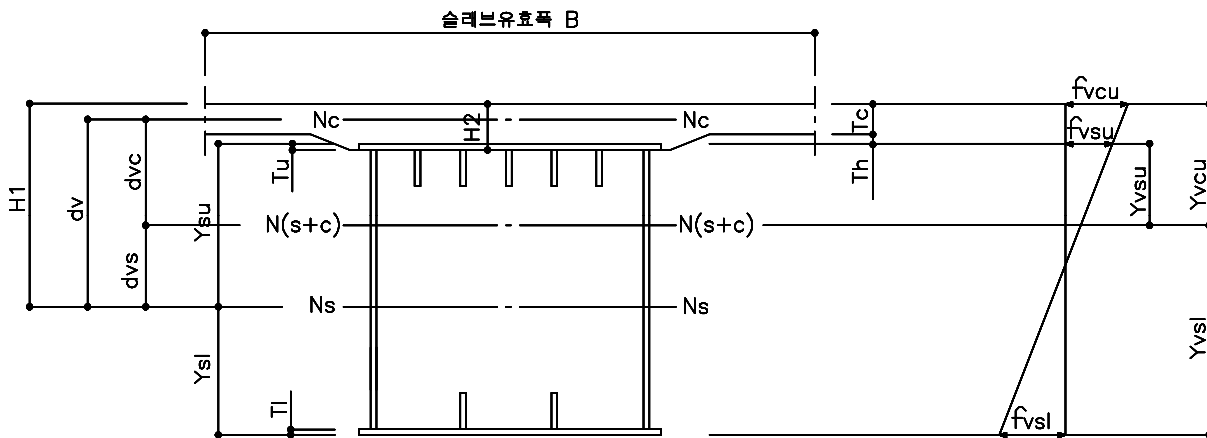
구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	5.768	16.200	0.K!!!	2.80
	크리프, 건조수축제외시	7.350	16.200	0.K!!!	2.20
상부플랜지	크리프, 건조수축 포함시	162.601	315.000	0.K!!!	1.93
	크리프, 건조수축제외시	145.003	315.000	0.K!!!	2.17
하부플랜지	크리프, 건조수축 포함시	-192.537	315.000	0.K!!!	1.63
	크리프, 건조수축제외시	-195.904	315.000	0.K!!!	1.60

단 면 제 원

단 면	B(mm)	H(mm)	A(mm ²)	Y(mm)	A*Y(mm ³)	A*Y2(mm ⁴)	Ix(mm ⁴)
1 - UPPER FLANGE	2700.0	12.0	32400	1356.0	43934400	59575046400	388800
5 - UPPER RIB	14.0	150.0	10500	1275.0	13387500	17069062500	19687500
1 - L_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
3 - LOWER RIB	14.0	150.0	6300	-1275.0	-8032500	10241437500	11812500
1 - LOWER FLANGE	2700.0	14.0	37800	-1357.0	-51294600	69606772200	617400
강단면 합계			151800		-2005200	1.56492E+11	39398506200
1 - RC SLAB	5951.0	200.0	1190200	1550.0	1844810000	2859455500000	3967333333

* As = 151800 mm² , Ac = 1190200 mm²

2) 응 력 검 토



(1) 합 성 전

$$I_{s'} = A_s \cdot Y^2 + \sum I_s = ##### + 39398506200.0 = 195890824800 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -2005200 / 151800 = -13.209 \text{ mm}$$

$$I_s = I_{s'} - A_s \cdot \delta s^2 = ##### - 151800 \times (-13.209)^2 = 195864337138 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2700.0 / 2 + 12.0 - (-13.209) = 1375.209 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1375.209 - 2726.000 = -1350.791 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6815056.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 38.605 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = -37.920 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 0.047 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 300575.0 \text{ mm}^2$$

$$I_{c/n} = 495916667 \text{ mm}^4$$

$$I_{c/n} = 495916667 \text{ mm}^4$$

$$\begin{aligned}
dvs &= dv - dvc = 773.7 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 889.5 \text{ mm} \\
Yvcl &= Yvcu - Tc = 689.5 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 601.5 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2124.5 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 379964718805 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6846456.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.462 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.358 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 2.501 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -8.833 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.114 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 1.968 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.525 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 10.645 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -37.601 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 12.403 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 226187.5 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1049.1 \text{ mm} & K = -0.090 \\
ds1 &= dv - dc1 = 514.1 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1149.1 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 949.1 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 861.1 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1864.9 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 318106022064 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 488303 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 488303 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 512282485 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.462 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.358 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.338 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.232 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 2.034 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = -12.403 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 201391.667 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1178.3 \text{ mm}$$

$$ds2 = dv - dc2 = 384.9 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1278.3 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1078.3 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 990.3 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1735.7 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 287372237252.4 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 1874565 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2208757115 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon_s = -1.224 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon_s = -1.218 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 8.623 \text{ MPa}$$

$$fvs12 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 10.509 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 3749130 \text{ N}$$

$$Mvt = P1 \cdot dvc = 2959828839 \text{ N} \cdot \text{mm}$$

$$fcut1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon_t = -1.723 \text{ MPa}$$

$$fclt1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon_t = -1.705 \text{ MPa}$$

$$fsut1 = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 12.052 \text{ MPa}$$

$$fslt1 = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 13.963 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 12.564 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(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	38.605	-37.920	148.183	190.000
1+2+3	2.430	1.884	10.800	10.800	51.751	-84.354	148.183	190.000
1+2+3+4	2.092	1.652	10.800	10.800	53.785	-81.925	170.410	190.000
1+2+3+4+5	0.868	0.433	10.800	10.800	62.408	-71.416	170.410	190.000
1+2+3+4+5+6	-0.855	-1.272	2.174	2.174	74.460	-57.453	192.638	218.500
1+2+3+4+5-6	2.591	2.139	12.420	12.420	50.357	-85.378	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)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{74.460}{192.638} \right)^2 + \left(\frac{12.564}{110.000} \right)^2$$

$$= 0.149 + 0.013 = 0.162 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-84.354}{190.000} \right)^2 + \left(\frac{12.564}{110.000} \right)^2$$

$$= 0.197 + 0.013 = 0.210 < 1.2 \quad \mathbf{O.K.}$$

(10) 판의 최소두께 검토

압축(상부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = 10 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K. (합성형 스퍼드 설치)}$$

인장(하부)플랜지 (☞ 도.설.기 3.8.3.1 및 3.8.3.2)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/38.605)} = 2.218 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 4.6 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/74.46)} = 1.597 > 1.2 \Rightarrow 1.200$$

(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

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.462 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 2.43 - 0.462 = 1.968 \text{ MPa}$$

$$\Sigma f = 1.3 \times 0.462 + 2.15 \times 1.968 + (-0.338) + (-1.224) + (1.723) \\ = 4.993 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times 0.462 + 2.15 \times 1.968 + (1.723) \\ = 6.555 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 38.605 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 2.501 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 51.751 - 38.605 - 2.501 = 10.646 \text{ MPa}$$

$$\Sigma f = 1.3 \times (38.605 + 2.501) + 2.15 \times 10.646 + (2.034) + (8.623) + (12.052) \\ = 99.034 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (38.605 + 2.501) + 2.15 \times 10.646 + (12.052) \\ = 88.377 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -37.920 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -8.833 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -84.354 - -37.92 - -8.833 = -37.601 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-37.92 + -8.833) + 2.15 \times -37.601 + (2.429) + (10.509) + (-13.963) \\ = -142.646 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

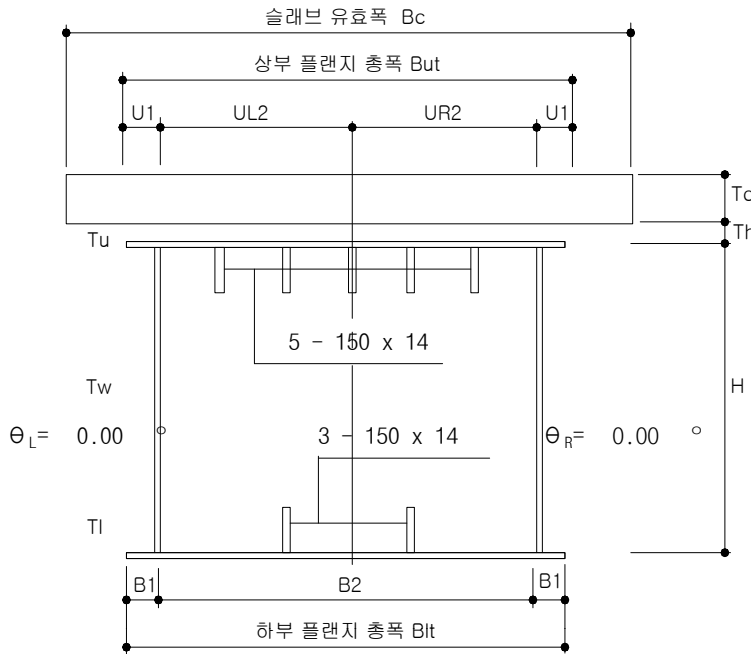
$$\Sigma f = 1.3 \times (-37.92 + -8.833) + 2.15 \times -37.601 + (-13.963) \\ = -155.583 \text{ MPa} < f_y = 315.0 \text{ MPa}$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	4.993	16.200	0.K!!!	3.24
	크리프, 건조수축제외시	6.555	16.200	0.K!!!	2.47
상부플랜지	크리프, 건조수축 포함시	99.034	315.000	0.K!!!	3.18
	크리프, 건조수축제외시	88.377	315.000	0.K!!!	3.56
하부플랜지	크리프, 건조수축 포함시	-142.646	315.000	0.K!!!	2.20
	크리프, 건조수축제외시	-155.583	315.000	0.K!!!	2.02

5-7. 6경간 최대 정모멘트 단면검토(G2)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.700 m

Bc = 5.951 m

UL2= 1.250 , UR2= 1.250 m

B2 = 2.500 m

But= 2.700 , Bit= 2.700 m

상하 플랜지 유효폭

Bue= 2.700 , Ble= 2.700 m

Tc = 0.200 m

Th = 0.100 m

Tu = 0.012 m

TI = 0.014 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	5498.380
Msc : 합성후 고정하중에 의한 모멘트	kN · m	1579.670
Mv : 활하중+지점침하에 의한 모멘트	kN · m	6724.852
Ss : 합성전 고정하중에 의한 전단력	kN	3.000
Ssc : 합성후 고정하중에 의한 전단력	kN	6.710
Sv : 활하중+지점침하에 의한 전단력	kN	410.491
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-0.100
Msct : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-1.770
Mvt : 활하중+지점침하에 의한 비틀림모멘트	kN · m	305.184

< 참고 > 합성전 고정하중 : 강재자중 + 바닥판콘크리트자중

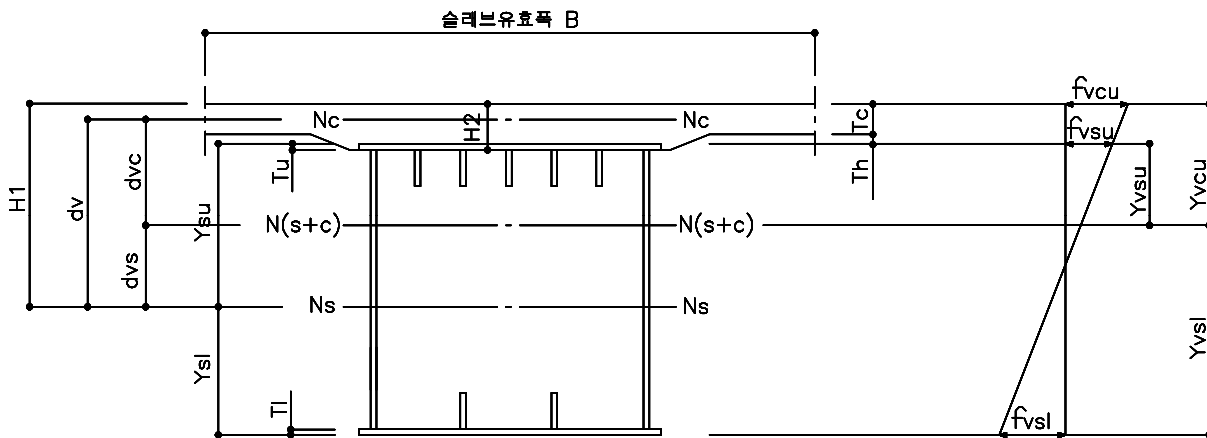
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	12.0	32400	1356.0	43934400	59575046400	388800
5 - UPPER RIB	14.0	150.0	10500	1275.0	13387500	17069062500	19687500
1 - L_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
3 - LOWER RIB	14.0	150.0	6300	-1275.0	-8032500	10241437500	11812500
1 - LOWER FLANGE	2700.0	14.0	37800	-1357.0	-51294600	69606772200	617400
강단면 합계			151800		-2005200	1.56492E+11	39398506200
1 - RC SLAB	5951.0	200.0	1190200	1550.0	1844810000	2859455500000	3967333333

* As = 151800 mm² , Ac = 1190200 mm²

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = ##### + 39398506200.0 = 195890824800 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -2005200 / 151800 = -13.209 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = ##### - 151800 \times (-13.209)^2 = 195864337138 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2700.0 / 2 + 12.0 - (-13.209) = 1375.209 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1375.209 - 2726.000 = -1350.791 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6815056.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 38.605 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = -37.920 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 0.047 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 300575.0 \text{ mm}^2$$

$$I_c/n = 495916667 \text{ mm}^4$$

$$I_{cn} = I_c/n + A_v \cdot Y_{cn}^2 = 495916667 + 300575.0 \cdot 1550.0^2 = 7189166667$$

$$\begin{aligned}
dvs &= dv - dvc = 773.7 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 889.5 \text{ mm} \\
Yvcl &= Yvcu - Tc = 689.5 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 601.5 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2124.5 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 379964718805 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6846456.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.462 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.358 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 2.501 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -8.833 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 0.114 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 1.968 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.525 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 10.645 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -37.601 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 8.192 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 226187.5 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1049.1 \text{ mm} & K = -0.090 \\
ds1 &= dv - dc1 = 514.1 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1149.1 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 949.1 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 861.1 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1864.9 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 318106022064 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 488303 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 488303 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 512282485 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.462 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.358 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.338 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.232 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 2.034 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = -8.422 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 201391.667 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1178.3 \text{ mm}$$

$$ds2 = dv - dc2 = 384.9 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1278.3 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1078.3 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 990.3 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1735.7 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 287372237252.4 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 1874565 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2208757115 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon_s = -1.224 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon_s = -1.218 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 8.623 \text{ MPa}$$

$$fvs12 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 10.509 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 3749130 \text{ N}$$

$$Mvt = P1 \cdot dvc = 2959828839 \text{ N} \cdot \text{mm}$$

$$fcut1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon_t = -1.723 \text{ MPa}$$

$$fclt1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon_t = -1.705 \text{ MPa}$$

$$fsut1 = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 12.052 \text{ MPa}$$

$$fslt1 = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 13.963 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 8.331 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(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	38.605	-37.920	148.183	190.000
1+2+3	2.430	1.884	10.800	10.800	51.751	-84.354	148.183	190.000
1+2+3+4	2.092	1.652	10.800	10.800	53.785	-81.925	170.410	190.000
1+2+3+4+5	0.868	0.433	10.800	10.800	62.408	-71.416	170.410	190.000
1+2+3+4+5+6	-0.855	-1.272	2.174	2.174	74.460	-57.453	192.638	218.500
1+2+3+4+5-6	2.591	2.139	12.420	12.420	50.357	-85.378	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)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{74.460}{192.638} \right)^2 + \left(\frac{8.331}{110.000} \right)^2$$

$$= 0.149 + 0.006 = 0.155 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-84.354}{190.000} \right)^2 + \left(\frac{8.331}{110.000} \right)^2$$

$$= 0.197 + 0.006 = 0.203 < 1.2 \quad \mathbf{O.K.}$$

(10) 판의 최소두께 검토

압축(상부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = 10 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K. (합성형 스퍼드 설치)}$$

인장(하부)플랜지 (☞ 도.설.기 3.8.3.1 및 3.8.3.2)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 14 \text{ mm} \quad \text{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{f_{ca}/f_c} = \sqrt{(190/38.605)} = 2.218 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 4.6 \text{ mm} \leq t = 12 \text{ mm} \quad \text{O.K.}$$

$$\text{여기서, } \sqrt{f_{ca}/f_c} = \sqrt{(190/74.46)} = 1.597 > 1.2 \Rightarrow 1.200$$

(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

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.462 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 2.43 - 0.462 = 1.968 \text{ MPa}$$

$$\Sigma f = 1.3 \times 0.462 + 2.15 \times 1.968 + (-0.338) + (-1.224) + (1.723) \\ = 4.993 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times 0.462 + 2.15 \times 1.968 + (1.723) \\ = 6.555 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 38.605 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 2.501 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 51.751 - 38.605 - 2.501 = 10.646 \text{ MPa}$$

$$\Sigma f = 1.3 \times (38.605 + 2.501) + 2.15 \times 10.646 + (2.034) + (8.623) + (12.052) \\ = 99.034 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (38.605 + 2.501) + 2.15 \times 10.646 + (12.052) \\ = 88.377 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 제외시)}$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -37.920 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -8.833 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -84.354 - (-37.92) - (-8.833) = -37.601 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-37.92 + -8.833) + 2.15 \times -37.601 + (2.429) + (10.509) + (-13.963) \\ = -142.646 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \text{O.K. (크리프, 건조수축 포함시)}$$

$$\Sigma f = 1.3 \times (-37.92 + -8.833) + 2.15 \times -37.601 + (-13.963) \\ = -155.583 \text{ MPa} < f_y = 315.0 \text{ MPa}$$

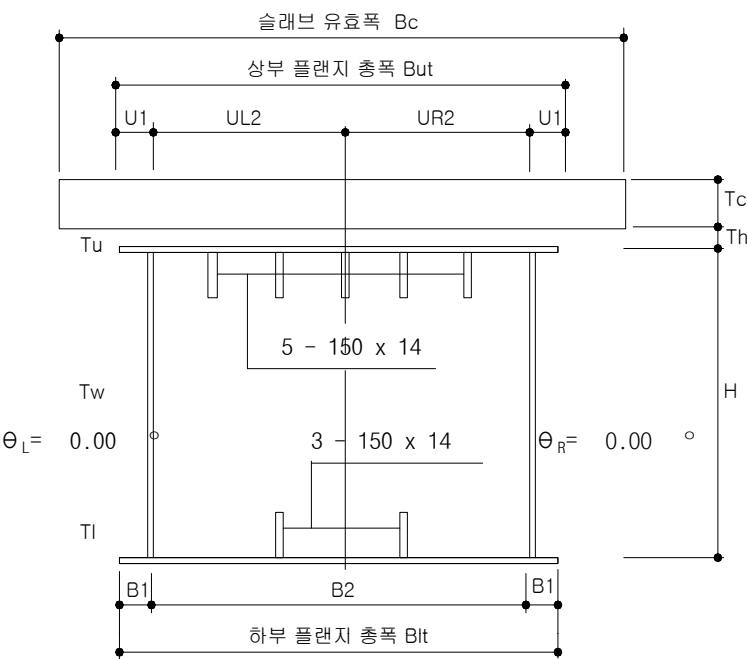
- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	4.993	16.200	0.K!!!	3.24
	크리프, 건조수축제외시	6.555	16.200	0.K!!!	2.47
상부플랜지	크리프, 건조수축 포함시	99.034	315.000	0.K!!!	3.18
	크리프, 건조수축제외시	88.377	315.000	0.K!!!	3.56
하부플랜지	크리프, 건조수축 포함시	-142.646	315.000	0.K!!!	2.20
	크리프, 건조수축제외시	-155.583	315.000	0.K!!!	2.02

5-8. 7경간 최대 정모멘트 단면검토(G2)

1) 단면가정 및 설계조건

주부재사용강종 = SM490



H = 2.700 m
Bc = 6.042 m
UL2= 1.250 , UR2= 1.250 m
B2 = 2.500 m
But= 2.700 , Bit= 2.700 m
상하 플랜지 유효폭
Bue= 2.700 , Ble= 2.700 m
Tc = 0.200 m
Th = 0.100 m
Tu = 0.016 m
Tl = 0.020 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 : 강 의 탄성계수	MPa	210000
Ec : 콘크리트 의 탄성계수	MPa	26702
εs: 바닥판 콘크리트 의 건조수축에 의한 최종수축율		0.00018
α : 강재 및 콘크리트 의 선팽창계수		0.000012
φ2: 건조수축에 의한 크리이프계수		4
n : 강과 콘크리트 의 탄성계수비		8
t : 강과 콘크리트 의 온도차	℃	10
Ms : 합성전 고정하중에 의한 모멘트	kN · m	12873.070
Msc : 합성후 고정하중에 의한 모멘트	kN · m	3485.380
Mv : 활하중+지점침하에 의한 모멘트	kN · m	8507.966
Ss : 합성전 고정하중에 의한 전단력	kN	209.400
Ssc : 합성후 고정하중에 의한 전단력	kN	61.230
Sv : 활하중+지점침하에 의한 전단력	kN	372.720
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	1.000
Msct : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-9.530
Mvt : 활하중+지점침하에 의한 비틀림모멘트	kN · m	-334.702

< 참고 > 합성전 고정하중 : 강재자중 + 바닥판콘크리트자중

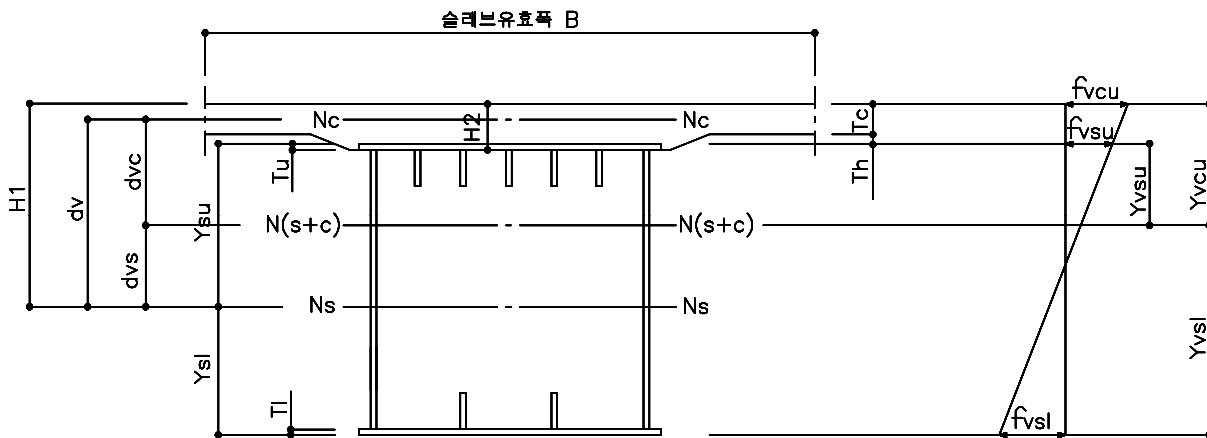
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	1358.0	58665600	79667884800	921600
5 - UPPER RIB	14.0	150.0	10500	1275.0	13387500	17069062500	19687500
1 - L_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.0	0	0	19683000000
3 - LOWER RIB	14.0	150.0	6300	-1275.0	-8032500	10241437500	11812500
1 - LOWER FLANGE	2700.0	20.0	54000	-1360.0	-73440000	99878400000	1800000
강단면 합계			178800		-9419400	2.06857E+11	39400221600
1 - RC SLAB	6042.0	200.0	1208400	1550.0	1873020000	2903181000000	4028000000

* As = 178800 mm² , Ac = 1208400 mm²

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = ##### + 39400221600.0 = 246257006400 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -9419400 / 178800 = -52.681 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = ##### - 178800 \times (-52.681)^2 = 245760781029 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2700.0 / 2 + 16.0 - (-52.681) = 1418.681 \text{ mm}$$

$$Y_{sI} = Y_{su} - (H + T_u + T_l) = 1418.681 - 2736.000 = -1317.319 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + T_u/2 + T_l/2) = 6827616.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = 74.311 \text{ MPa}$$

$$f_{sI} = M_s \cdot Y_{sI} / I_s = -69.002 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 3.238 \text{ MPa}$$

(2) 합 성 후

$$A_v = A_s + A_c/n = 329850.0 \text{ mm}^2$$

$$I_c/n = 503500000 \text{ mm}^4$$

$$I_{cn} = 1000000000 \text{ mm}^4$$

$$\begin{aligned}
dvs &= dv - dvc = 733.9 \text{ mm} \\
Yvcu &= dvc + Tc/2 = 968.8 \text{ mm} \\
Yvcl &= Yvcu - Tc = 768.8 \text{ mm} \\
Yvsu &= Yvcu - H2 + Tu = 684.8 \text{ mm} \\
Yvsl &= Yvsu - (H + Tu + Tl) = -2051.2 \text{ mm} \\
Iv &= Is + Ic/n + As \cdot dvs^2 + Ac/n \cdot dvc^2 = 456577245526 \text{ mm}^4 \\
Fv &= b \cdot hv = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + (Tu + Tc/n)/2 + Tl/2) = 6859016.0 \text{ mm}^2 \\
fvcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.924 \text{ MPa} \\
fvcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.734 \text{ MPa} \\
fvsu &= Msc \cdot Yvsu / Iv = 5.227 \text{ MPa} \\
fvsl &= Msc \cdot Yvsl / Iv = -15.659 \text{ MPa} \\
u &= Ssc / A(Web) + Msct / (2 \cdot Fv \cdot Tw) = 1.003 \text{ MPa}
\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}
fvcu &= Mv \cdot Yvcu / (n \cdot Iv) = 2.257 \text{ MPa} \\
fvcl &= Mv \cdot Yvcl / (n \cdot Iv) = 1.791 \text{ MPa} \\
fvsu &= Mv \cdot Yvsu / Iv = 12.760 \text{ MPa} \\
fvsl &= Mv \cdot Yvsl / Iv = -38.223 \text{ MPa} \\
u &= Sv / A(Web) + Mvt / (2 \cdot Fv \cdot Tw) = 7.785 \text{ MPa}
\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}
n1 &= n \cdot (1 + \phi 1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\
Av1 &= As + Ac/n1 = 254325.0 \text{ mm}^2 & \# \text{ 2차 부정정력으로 인한 영향 고려} \\
dc1 &= dv \cdot As / (Ac/n1 + As) = 1126.7 \text{ mm} & K = 0.530 \\
ds1 &= dv - dc1 = 475.9 \text{ mm} \\
Yv1cu &= dc1 + Tc/2 = 1226.7 \text{ mm} \\
Yv1cl &= Yv1cu - Tc = 1026.7 \text{ mm} \\
Yv1su &= Yv1cu - H2 + Tu = 942.7 \text{ mm} \\
Yv1sl &= Yv1su - (H + Tu + Tl) = -1793.3 \text{ mm} \\
Iv1 &= Is + Ic/n1 + As \cdot ds1^2 + Ac/n1 \cdot dc1^2 = 382396550176 \text{ mm}^4 \\
Nc &= Msc \cdot dvc \cdot Ac / (n \cdot Iv) = 1001739 \text{ N} \\
P\phi &= Nc \cdot 2 \cdot \phi 1 / (2 + \phi 1) = 1001739 \text{ N} \\
M\phi &= P\phi \cdot dc1 = 1128704814 \text{ N} \cdot \text{mm} \\
Ec1 &= Ec / (1 + \phi 1 / 2) = 13351 \text{ MPa} \\
fcu &= Msc \cdot Yvcu / (n \cdot Iv) = 0.924 \text{ MPa} \\
fcl &= Msc \cdot Yvcl / (n \cdot Iv) = 0.734 \text{ MPa} \\
fvcu1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cu / Iv1) - Ec1 \cdot fcu \cdot \phi 1 / Ec = -0.558 \text{ MPa} \\
fvcl1 &= 1/n1 \cdot (P\phi / Av1 + k \cdot M\phi \cdot Yv1cl / Iv1) - Ec1 \cdot fcl \cdot \phi 1 / Ec = -0.387 \text{ MPa} \\
fvsu1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1su / Iv1 = 5.414 \text{ MPa} \\
fvsl1 &= P\phi / Av1 + k \cdot M\phi \cdot Yv1sl / Iv1 = 4.422 \text{ MPa}
\end{aligned}$$

(5) 건 조 수 축

$$n2 = n \cdot (1 + \phi^2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$Av2 = As + Ac/n2 = 229150.000 \text{ mm}^2$$

$$dc2 = dv \cdot As / (Ac/n2 + As) = 1250.5 \text{ mm}$$

$$ds2 = dv - dc2 = 352.1 \text{ mm}$$

$$Yv2cu = dc2 + Tc/2 = 1350.5 \text{ mm}$$

$$Yv2cl = Yv2cu - Tc = 1150.5 \text{ mm}$$

$$Yv2su = Yv2cu - H2 + Tu = 1066.5 \text{ mm}$$

$$Yv2sl = Yv2su - (H + Tu + Tl) = -1669.5 \text{ mm}$$

$$Iv2 = Is + Ic/n2 + As \cdot ds2^2 + Ac/n2 \cdot dc2^2 = 346840289886.7 \text{ mm}^4$$

$$P2 = Es \cdot \epsilon_s \cdot Ac/n2 = 1903230 \text{ N}$$

$$Mv2 = P2 \cdot dc2 = 2380049954 \text{ N} \cdot \text{mm}$$

$$Ec2 = Es \cdot /n2 = 8750 \text{ MPa}$$

$$fvcu2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cu/Iv2) - Ec2 \cdot \epsilon_s = -1.024 \text{ MPa}$$

$$fvcl2 = 1/n2 \cdot (P2/Av2 + k \cdot Mv2 \cdot Yv2cl/Iv2) - Ec2 \cdot \epsilon_s = -1.055 \text{ MPa}$$

$$fvsu2 = P2/Av2 + k \cdot Mv2 \cdot Yv2su/Iv2 = 12.184 \text{ MPa}$$

$$fvsl2 = P2/Av2 + k \cdot Mv2 \cdot Yv2sl/Iv2 = 2.234 \text{ MPa}$$

(6) 온 도 차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P1 = Es \cdot \epsilon_t \cdot Ac/n = 3806460 \text{ N}$$

$$Mvt = P1 \cdot dvc = 3306887657 \text{ N} \cdot \text{mm}$$

$$fcut1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcu/Iv) - Ec \cdot \epsilon_t = -1.297 \text{ MPa}$$

$$fclt1 = 1/n \cdot (P1/Av + k \cdot Mvt \cdot Yvcl/Iv) - Ec \cdot \epsilon_t = -1.393 \text{ MPa}$$

$$fsut1 = P1/Av + k \cdot Mvt \cdot Yvsu/Iv = 14.169 \text{ MPa}$$

$$fslt1 = P1/Av + k \cdot Mvt \cdot Yvsl/Iv = 3.666 \text{ MPa}$$

(7) 전 단 및 비틀림

$$u = (Ss + Ssc + Sv)/Aw + Mst/(2 F Tw) + (Msc + Mvt)/(2 FvTw) = 12.013 \text{ MPa} < u_a = 110 \text{ MPa} \quad \text{O.K.}$$

(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	74.311	-69.002	182.038	190.000
1+2+3	3.181	2.524	10.800	10.800	92.298	-122.884	182.038	190.000
1+2+3+4	2.623	2.137	10.800	10.800	97.712	-121.750	209.344	190.000
1+2+3+4+5	1.598	1.083	10.800	10.800	109.896	-119.516	209.344	190.000
1+2+3+4+5+6	0.301	-0.310	12.420	2.174	124.065	-115.850	236.649	218.500
1+2+3+4+5-6	2.895	2.475	12.420	12.420	95.728	-123.182	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)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{109.896}{209.344} \right)^2 + \left(\frac{12.013}{110.000} \right)^2$$

$$= 0.276 + 0.012 = 0.288 < 1.2 \quad \mathbf{O.K.}$$

(하 연)

$$\left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 = \left(\frac{-122.884}{190.000} \right)^2 + \left(\frac{12.013}{110.000} \right)^2$$

$$= 0.412 + 0.012 = 0.424 < 1.2 \quad \mathbf{O.K.}$$

(10) 판의 최소두께 검토

압축(상부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 16 \text{ mm} \quad \mathbf{O.K.}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 16 \text{ mm} \quad \mathbf{O.K.}$$

$$t_{min} = 10 \text{ mm} \leq t = 16 \text{ mm} \quad \mathbf{O.K.} \quad (\text{합성형 스테드 설치})$$

인장(하부)플랜지 (☞ 도.설.기 3.8.3.1 및 3.8.3.2)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 20 \text{ mm} \quad \mathbf{O.K.}$$

$$t_{min} = b / (80 \cdot n) = 2500 / (80 \times 4) = 7.8 \text{ mm} \leq t = 20 \text{ mm} \quad \mathbf{O.K.}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/74.311)} = 1.599 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = bc / (219 \times 1.200) = 5.2 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{O.K.}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190/124.065)} = 1.238 > 1.2 \Rightarrow 1.200$$

(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

$$\text{합성후 사하중 응력} = \{ M_{sc} / (n \cdot I_v) \} \times Y_{vcu} = 0.924 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 3.181 - 0.924 = 2.257 \text{ MPa}$$

$$\Sigma f = 1.3 \times 0.924 + 2.15 \times 2.257 + (-0.558) + (-1.024) + (1.297) = 5.768 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \mathbf{O.K.} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times 0.924 + 2.15 \times 2.257 + (1.297) = 7.350 \text{ MPa} < (3/5) f_{ck} = 16.2 \text{ MPa} \quad \mathbf{O.K.} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = 74.311 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsu} = 5.227 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 92.298 - 74.311 - 5.227 = 12.760 \text{ MPa}$$

$$\Sigma f = 1.3 \times (74.311 + 5.227) + 2.15 \times 12.76 + (5.414) + (12.184) + (14.169) = 162.601 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{O.K.} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (74.311 + 5.227) + 2.15 \times 12.76 + (14.169) = 145.003 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{O.K.} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = -69.002 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_v \times Y_{vsl} = -15.659 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -122.884 - (-69.002) - (-15.659) = -38.223 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-69.002 + -15.659) + 2.15 \times -38.223 + (1.133) + (2.234) + (-3.666) = -192.537 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{O.K.} \quad (\text{크리프, 건조수축 포함시})$$

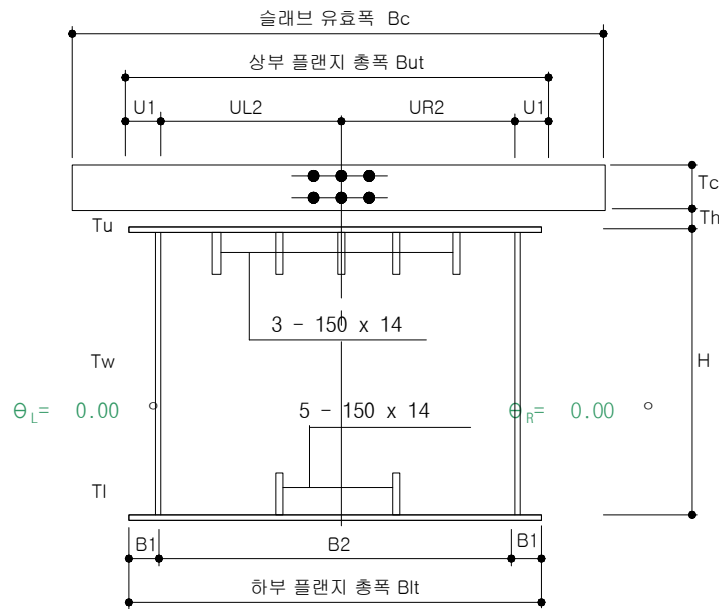
$$\Sigma f = 1.3 \times (-69.002 + -15.659) + 2.15 \times -38.223 + (-3.666) = -195.904 \text{ MPa} < f_y = 315.0 \text{ MPa}$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	5.768	16.200	0.K!!!	2.80
	크리프, 건조수축제외시	7.350	16.200	0.K!!!	2.20
상부플랜지	크리프, 건조수축 포함시	162.601	315.000	0.K!!!	1.93
	크리프, 건조수축제외시	145.003	315.000	0.K!!!	2.17
하부플랜지	크리프, 건조수축 포함시	-192.537	315.000	0.K!!!	1.63
	크리프, 건조수축제외시	-195.904	315.000	0.K!!!	1.60

5-9. 4경간 최대 부모멘트 단면검토(G1)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.700 m

Bc = 5.178 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 = 0.200 m

Th = 0.100 m

Tu = 0.030 m

Tl = 0.032 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	-20278.140
Msc : 합성후 고정하중에 의한 모멘트	kN · m	-4923.770
Mv : (활하중 + 지점침하)에 의한 모멘트	kN · m	-9066.297
Ss : 합성전 고정하중에 의한 전단력	kN	-1764.560
Ssc : 합성후 고정하중에 의한 전단력	kN	-412.210
Sv : (활하중 + 지점침하)에 의한 전단력	kN	-895.392
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-0.250
Mscst : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-35.110
Mvt : (활하중 + 지점침하)에 의한 비틀림모멘트	kN · m	-931.278
tcu,tcl : 교축방향 철근의 피복두께	mm	50 , 50

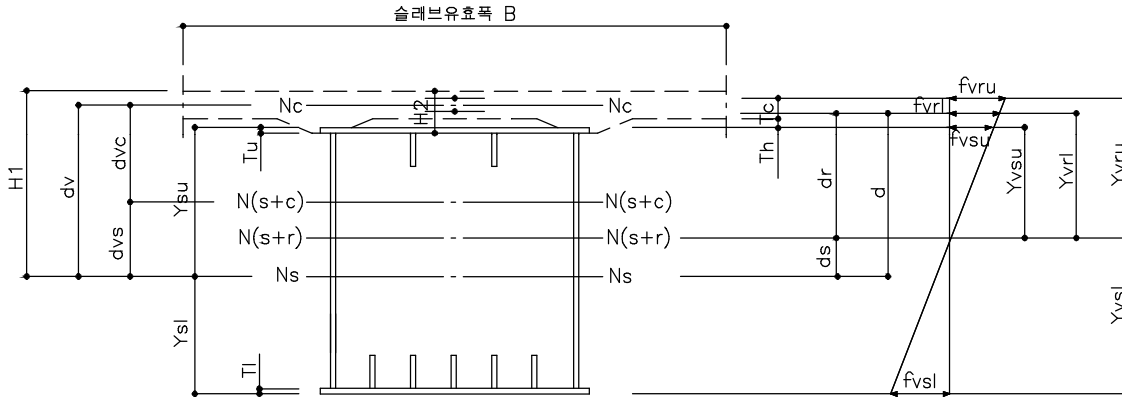
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

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)
- UPPER FLANGE	2432.0	30.0	72960	1365.00	99590400	135940896000	5472000
- UPPER RIB	14.0	150.0	6300	1275.00	8032500	10241437500	11812500
- L_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
- R_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
- LOWER RIB	14.0	150.0	10500	-1275.00	-13387500	17069062500	19687500
- LOWER FLANGE	2432.0	32.0	77824	-1366.00	-106307584	145216159744	6640981
강단면 합계			232384		-12072184	308467555744	39409612981
UPPER RE-BAR	-	-	4269.90	1600.00	6831840	10930944000	-
LOWER RE-BAR	-	-	6255.90	1500.00	9383850	14075775000	-
RE-BAR 합계			10526		16215690	25006719000	-
- RC SLAB	5178.0	200.0	1035600	1550.00	1605180000	2488029000000	3452000000

$$* A_s = 232384 \text{ mm}^2, A_c = 1035600 \text{ mm}^2, A_r = 10526 \text{ mm}^2$$

2) 응력 검토



(1) 합 성 전

$$I_s' = A_s \cdot Y_2 + \sum I_s = 308467555744 + 39409612981 = 347877168725 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -12072184 / 232384 = -51.949 \text{ mm}$$

$$I_s = I_{s'} - A_s \cdot \delta s^2 = 347877168725 - 232384 \times -51.949^2 = 347250027328 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta_s = 2700.0 / 2 + 30.0 - -51.949 = 1431.949 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1431.949 - 2762.000 = -1330.051 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6860272.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = -83.621 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = 77.670 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot T_w) = 27.232 \text{ MPa}$$

(2) 합 성 후

$$\begin{aligned}A_v &= A_s + A_r = 242910 \text{ mm}^2 \\d &= Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1592.515 \text{ mm} \\d_r &= d \cdot A_s / (A_s + A_r) = 1523.508 \text{ mm} \\d_s &= d - d_r = 69.007 \text{ mm} \\Y_{vru} &= d_r + (T_c - t_{cu} - t_{cl}) \cdot A_{rl}/A_r = 1582.942 \text{ mm} \\Y_{vrl} &= d_r - (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1482.942 \text{ mm} \\Y_{vsu} &= Y_{vrl} - t_{cl} - T_h + T_u = 1362.942 \text{ mm} \\Y_{vsl} &= Y_{vsu} - (H + T_u + T_l) = -1399.058 \text{ mm} \\I_{rv} &= I_s + A_s \cdot d_s^2 + A_r \cdot d_r^2 = 372787830935 \text{ mm}^4 \\F_v &= b \cdot h_v = ((UL2 + UR2 + B2) / 2 + T_w) \cdot (H + (T_u + T_c/n)/2 + T_l/2) = 6891672.0 \text{ mm}^2 \\f_{vru} &= M_{sc} \cdot Y_{vru}/I_{rv} = -20.907 \text{ MPa} \\f_{vrl} &= M_{sc} \cdot Y_{vrl}/I_{rv} = -19.587 \text{ MPa} \\f_{vsu} &= M_{sc} \cdot Y_{vsu}/I_{rv} = -18.002 \text{ MPa} \\f_{vsl} &= M_{sc} \cdot Y_{vsl}/I_{rv} = 18.479 \text{ MPa} \\u &= S_{sc} / A(\text{Web}) + M_{sct} / (2 \cdot F_v \cdot T_w) = 6.574 \text{ MPa}\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}f_{vru} &= M_v \cdot Y_{vru}/I_{rv} = -38.498 \text{ MPa} \\f_{vrl} &= M_v \cdot Y_{vrl}/I_{rv} = -36.066 \text{ MPa} \\f_{vsu} &= M_v \cdot Y_{vsu}/I_{rv} = -33.147 \text{ MPa} \\f_{vsl} &= M_v \cdot Y_{vsl}/I_{rv} = 34.025 \text{ MPa} \\u &= S_v / A(\text{Web}) + M_{vt} / (2 \cdot F_v \cdot T_w) = 19.448 \text{ MPa}\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}A_{vc} &= A_s + A_c/n = 361834.000 \text{ mm}^2 \\d_v &= Y_{su} - T_u + T_h + T_c/2 = 1601.949 \text{ mm} \\d_{vc} &= d_v \cdot A_s / (A_c/n + A_s) = 1028.835 \text{ mm} \\d_{vs} &= d_v - d_{vc} = 573.115 \text{ mm} \\n_1 &= n \cdot (1 + \phi_1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\A_{v1} &= A_s + A_c/n_1 = 297109.000 \text{ mm}^2 \quad \# \text{ 2차 부정정력으로 인한 영향 고려} \\d_{c1} &= d_v \cdot A_s / (A_c/n_1 + A_s) = 1252.966 \text{ mm} \quad K = -0.300 \\d_{s1} &= d_v - d_{c1} = 348.984 \text{ mm} \\I_{cv} &= I_s + I_c/n + A_s \cdot d_{vs}^2 + A_c/n \cdot d_{vc}^2 = 561033387363.6 \text{ mm}^4 \\N_c &= M_{sc} \cdot d_{vc} \cdot A_c/(n \cdot I_{cv}) = -1168844 \text{ N} \\P\phi &= N_c \cdot 2 \cdot \phi_1 / (2 + \phi_1) = -1168844 \text{ N} \\M\phi &= P\phi \cdot d_{c1} = -1464521998 \text{ N} \cdot \text{mm} \\E_{c1} &= E_c / (1 + \phi_1 / 2) = 13351 \text{ MPa} \\f_{vru1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vru}/I_{rv} = -2.946 \text{ MPa} \\f_{vrl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vrl}/I_{rv} = -3.064 \text{ MPa} \\f_{vsu1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsu} / I_{rv} = -3.206 \text{ MPa} \\f_{vsl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsl} / I_{rv} = -6.461 \text{ MPa}\end{aligned}$$

(5) 건조수축

$$n_2 = n \cdot (1 + \phi_2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$A_{v2} = A_s + A_c/n_2 = 275534.000 \text{ mm}^2$$

$$d_{c2} = d_v \cdot A_s / (A_c/n_2 + A_s) = 1351.076 \text{ mm}$$

$$d_{s2} = d_v - d_{c2} = 250.873 \text{ mm}$$

$$P_2 = E_s \cdot \epsilon_s \cdot A_c/n_2 = 1631070 \text{ N}$$

$$M_{v2} = P_2 \cdot d_{c2} = 2203699587 \text{ N} \cdot \text{mm}$$

$$f_{vru2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vru}/I_{rv} = 3.907 \text{ MPa}$$

$$f_{vrl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vrl}/I_{rv} = 4.085 \text{ MPa}$$

$$f_{vsu2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsu}/I_{rv} = 4.298 \text{ MPa}$$

$$f_{vsl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsl}/I_{rv} = 9.196 \text{ MPa}$$

(6) 온도차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P_1 = E_s \cdot \epsilon_t \cdot A_c/n = 3262140 \text{ N}$$

$$M_{vt} = P_1 \cdot d_{vc} = 3356202911 \text{ N} \cdot \text{mm}$$

$$E_{rt} = E_s \cdot \epsilon_t = 25.200 \text{ MPa}$$

$$f_{rut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vru}/I_{rv} - E_s \cdot \epsilon_t = -16.046 \text{ MPa}$$

$$f_{rllt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vrl}/I_{rv} - E_s \cdot \epsilon_t = -15.776 \text{ MPa}$$

$$f_{sut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsu}/I_{rv} = 9.748 \text{ MPa}$$

$$f_{slt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsl}/I_{rv} = 17.208 \text{ MPa}$$

(7) 전단 및 비틀림

$$u = (S_s + S_{sc} + S_v)/A_w + (M_{st}/(2 F T_w) + (M_{sct} + M_{vt})/(2 F_v T_w)) = 53.254 \text{ MPa} < u_a = 110 \text{ MPa} \quad 0.K!!!$$

(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 : $f_{ca} = 190 - 3.9 (b / (t_l \cdot i \cdot n) - 24) = 232.819$

$$\frac{b}{49 \cdot i \cdot n} > t_l \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.208 \text{ mm}$$

인 경우 : $f_{ca} = 220000 \times \{ (t_l \cdot i \cdot n) / b \} = 1297.613 \text{ MPa}$

사용 $t_l = 32.0 \text{ mm}$

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	-83.621	77.670	190.000	190.000
1+2+3	-59.405	-55.652	160.000	-134.769	130.174	190.000	190.000
1+2+3+4	-62.351	-58.716	160.000	-137.975	123.714	190.000	190.000
1+2+3+4+5	-58.444	-54.631	160.000	-133.677	132.909	190.000	190.000
1+2+3+4+5+6	-74.490	-70.407	184.000	-123.929	150.118	218.500	218.500
1+2+3+4+5-6	-42.398	-38.856	184.000	-143.426	115.701	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)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{-137.975}{190.000} \right)^2 + \left(\frac{53.254}{110.000} \right)^2 \\ &= 0.527 + 0.234 = 0.762 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(하 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{132.909}{190.000} \right)^2 + \left(\frac{53.254}{110.000} \right)^2 \\ &= 0.489 + 0.234 = 0.724 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(10) 판의 최소두께 검토

인장(상부)플랜지 (도.설.기 3.8.3.1)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 30 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = 10 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K.} \quad (\text{합성형 스테드 설치})$$

압축(하부)플랜지 (도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K!!!}$$

복부판 수평보강재 사용단수 1 단 (도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 77.670)} = 1.564 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = b / (219 \times 1.125) = 11.0 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 150.118)} = 1.125 < 1.2 \Rightarrow 1.125$$

(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

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vru} = -20.907 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -59.405 - 20.907 = -38.498 \text{ MPa}$$

$$\Sigma f = 1.3 \times -20.907 + 2.15 \times -38.498 + (-2.946) + (3.907) + (-16.046) \\ = -125.034 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times -20.907 + 2.15 \times -38.498 + (-16.046) \\ = -125.995 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = -83.621 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsu} = -18.002 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -134.769 - 83.621 - 18.002 = -33.147 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-83.621 + -18.002) + 2.15 \times -33.147 + (-3.206) + (4.298) + (-9.748) \\ = -212.031 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (-83.621 + -18.002) + 2.15 \times -33.147 + (-9.748) \\ = -213.123 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = 77.670 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsl} = 18.479 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 130.174 - 77.67 - 18.479 = 34.026 \text{ MPa}$$

$$\Sigma f = 1.3 \times (77.67 + 18.479) + 2.15 \times 34.026 + (-6.461) + (9.196) + (17.208) \\ = 218.092 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

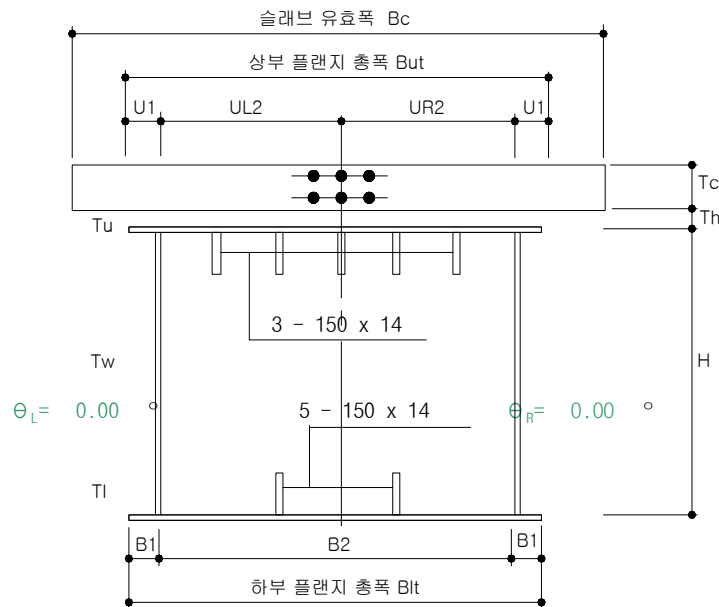
$$\Sigma f = 1.3 \times (77.67 + 18.479) + 2.15 \times 34.026 + (17.208) \\ = 215.356 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	-125.034	400.000	0.K!!!	3.19
	크리프, 건조수축제외시	-125.995	400.000	0.K!!!	3.17
상부플랜지	크리프, 건조수축 포함시	-212.031	315.000	0.K!!!	1.48
	크리프, 건조수축제외시	-213.123	315.000	0.K!!!	1.47
하부플랜지	크리프, 건조수축 포함시	218.092	315.000	0.K!!!	1.44
	크리프, 건조수축제외시	215.356	315.000	0.K!!!	1.46

5-10. 5경간 최대 부모멘트 단면검토(G1)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

$$H = 2.700 \text{ m}$$
$$B_c = 5.178 \text{ m}$$

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

$$T_c = 0.200 \text{ m}$$
$$T_h = 0.100 \text{ m}$$
$$T_u = 0.020 \text{ m}$$
$$T_I = 0.022 \text{ m}$$
$$T_w = 0.012 \text{ m}$$
$$U1 = 0.100 \text{ m}$$
$$B1 = 0.100 \text{ m}$$

RIB 150 x 14 mm , 150 x 14 mm

구 분	단 위	입력 DATA
Es : 강의 탄성계수	MPa	210000
Ec : 콘크리트의 탄성계수	MPa	26702
ϵ_s : 바닥판 콘크리트의 건조수축에의한 최종수축율		0.00018
α : 강재 및 콘크리트의 선팽창계수		0.000012
ϕ_2 : 건조수축에의한 크리이프계수		4
n : 강과 콘크리트의 탄성계수비		8
t : 강과 콘크리트의 온도차	℃	10
Ms : 합성전 고정하중에의한 모멘트	kN · m	-12613.500
Msc : 합성후 고정하중에의한 모멘트	kN · m	-3067.250
Mv : (활하중 + 지점침하)에의한 모멘트	kN · m	-8099.409
Ss : 합성전 고정하중에의한 전단력	kN	1160.240
Ssc : 합성후 고정하중에의한 전단력	kN	278.040
Sv : (활하중 + 지점침하)에의한 전단력	kN	674.450
Mst : 합성전 고정하중에의한 비틀림모멘트	kN · m	-0.240
Msct : 합성후 고정하중에의한 비틀림모멘트	kN · m	-19.590
Mvt : (활하중 + 지점침하)에의한 비틀림모멘트	kN · m	-870.226
t _{cu} , t _{cl} : 교축방향 철근의 피복두께	mm	50 , 50

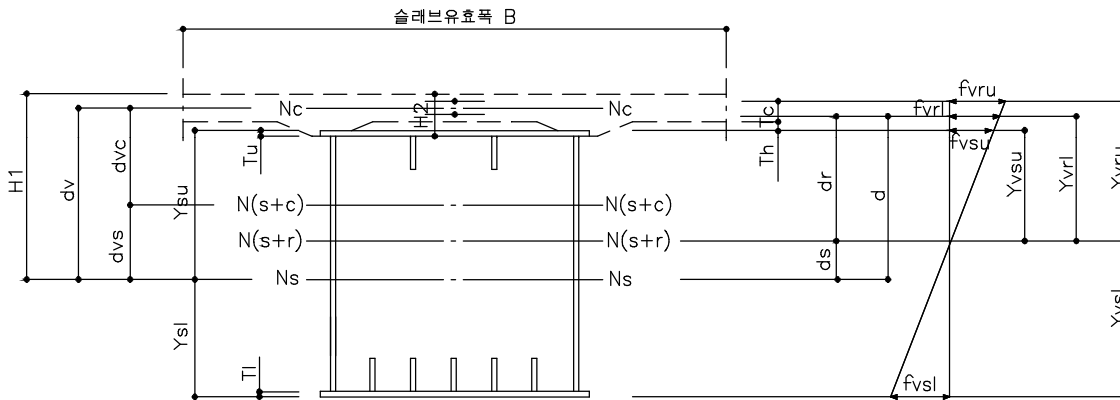
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	20.0	48640	1360.00	66150400	89964544000	1621333
3 - UPPER RIB	14.0	150.0	6300	1275.00	8032500	10241437500	11812500
1 - L_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
5 - LOWER RIB	14.0	150.0	10500	-1275.00	-13387500	17069062500	19687500
1 - LOWER FLANGE	2432.0	22.0	53504	-1361.00	-72818944	99106582784	2157995
강단면 합계			183744		-12023544	216381626784	39401279328
UPPER RE-BAR	-	-	4269.90	1600.00	6831840	10930944000	-
LOWER RE-BAR	-	-	6255.90	1500.00	9383850	14075775000	-
RE-BAR 합계			10526		16215690	25006719000	-
1 - RC SLAB	5178.0	200.0	1035600	1550.00	1605180000	2488029000000	3452000000

* $A_s = 183744 \text{ mm}^2$, $A_c = 1035600 \text{ mm}^2$, $A_r = 10526 \text{ mm}^2$

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = 216381626784 + 39401279328 = 255782906112 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -12023544 / 183744 = -65.436 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = 255782906112 - 183744 \times (-65.436)^2 = 254996128801 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2700.0 / 2 + 20.0 - (-65.436) = 1435.436 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1435.436 - 2742.000 = -1306.564 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6835152.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = -71.005 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = 64.630 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 17.906 \text{ MPa}$$

(2) 합 성 후

$$\begin{aligned}A_v &= A_s + A_r = 194270 \text{ mm}^2 \\d &= Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1606.002 \text{ mm} \\d_r &= d \cdot A_s / (A_s + A_r) = 1518.987 \text{ mm} \\d_s &= d - d_r = 87.015 \text{ mm} \\Y_{vru} &= d_r + (T_c - t_{cu} - t_{cl}) \cdot A_{rl}/A_r = 1578.421 \text{ mm} \\Y_{vrl} &= d_r - (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1478.421 \text{ mm} \\Y_{vsu} &= Y_{vrl} - t_{cl} - T_h + T_u = 1348.421 \text{ mm} \\Y_{vsl} &= Y_{vsu} - (H + T_u + T_l) = -1393.579 \text{ mm} \\I_{rv} &= I_s + A_s \cdot d_s^2 + A_r \cdot d_r^2 = 280673785129 \text{ mm}^4 \\F_v &= b \cdot h_v = ((UL2 + UR2 + B2) / 2 + T_w) \cdot (H + (T_u + T_c/n)/2 + T_l/2) = 6866552.0 \text{ mm}^2 \\f_{vru} &= M_{sc} \cdot Y_{vru}/I_{rv} = -17.249 \text{ MPa} \\f_{vrl} &= M_{sc} \cdot Y_{vrl}/I_{rv} = -16.156 \text{ MPa} \\f_{vsu} &= M_{sc} \cdot Y_{vsu}/I_{rv} = -14.736 \text{ MPa} \\f_{vsl} &= M_{sc} \cdot Y_{vsl}/I_{rv} = 15.229 \text{ MPa} \\u &= S_{sc} / A(\text{Web}) + M_{sct} / (2 \cdot F_v \cdot T_w) = 4.410 \text{ MPa}\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}f_{vru} &= M_v \cdot Y_{vru}/I_{rv} = -45.549 \text{ MPa} \\f_{vrl} &= M_v \cdot Y_{vrl}/I_{rv} = -42.663 \text{ MPa} \\f_{vsu} &= M_v \cdot Y_{vsu}/I_{rv} = -38.911 \text{ MPa} \\f_{vsl} &= M_v \cdot Y_{vsl}/I_{rv} = 40.215 \text{ MPa} \\u &= S_v / A(\text{Web}) + M_{vt} / (2 \cdot F_v \cdot T_w) = 15.689 \text{ MPa}\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}A_{vc} &= A_s + A_c/n = 313194.000 \text{ mm}^2 \\d_v &= Y_{su} - T_u + T_h + T_c/2 = 1615.436 \text{ mm} \\d_{vc} &= d_v \cdot A_s / (A_c/n + A_s) = 947.741 \text{ mm} \\d_{vs} &= d_v - d_{vc} = 667.696 \text{ mm} \\n_1 &= n \cdot (1 + \phi_1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\A_{v1} &= A_s + A_c/n_1 = 248469.000 \text{ mm}^2 \quad \# \text{ 2차 부정정력으로 인한 영향 고려} \\d_{c1} &= d_v \cdot A_s / (A_c/n_1 + A_s) = 1194.623 \text{ mm} \quad K = 0.160 \\d_{s1} &= d_v - d_{c1} = 420.814 \text{ mm} \\I_{cv} &= I_s + I_c/n + A_s \cdot d_{vs}^2 + A_c/n \cdot d_{vc}^2 = 453617525428.3 \text{ mm}^4 \\N_c &= M_{sc} \cdot d_{vc} \cdot A_c/(n \cdot I_{cv}) = -829566 \text{ N} \\P\phi &= N_c \cdot 2 \cdot \phi_1 / (2 + \phi_1) = -829566 \text{ N} \\M\phi &= P\phi \cdot d_{c1} = -991018623 \text{ N} \cdot \text{mm} \\E_{c1} &= E_c / (1 + \phi_1 / 2) = 13351 \text{ MPa} \\f_{vru1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vru}/I_{rv} = -5.162 \text{ MPa} \\f_{vrl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vrl}/I_{rv} = -5.105 \text{ MPa} \\f_{vsu1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsu} / I_{rv} = -5.032 \text{ MPa} \\f_{vsl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsl} / I_{rv} = -3.483 \text{ MPa}\end{aligned}$$

(5) 건조수축

$$n_2 = n \cdot (1 + \phi_2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$A_{v2} = A_s + A_c/n_2 = 226894.000 \text{ mm}^2$$

$$d_{c2} = d_v \cdot A_s / (A_c/n_2 + A_s) = 1308.218 \text{ mm}$$

$$d_{s2} = d_v - d_{c2} = 307.219 \text{ mm}$$

$$P_2 = E_s \cdot \epsilon_s \cdot A_c/n_2 = 1631070 \text{ N}$$

$$M_{v2} = P_2 \cdot d_{c2} = 2133794624 \text{ N} \cdot \text{mm}$$

$$f_{vru2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vru}/I_{rv} = 10.316 \text{ MPa}$$

$$f_{vrl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vrl}/I_{rv} = 10.194 \text{ MPa}$$

$$f_{vsu2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsu}/I_{rv} = 10.036 \text{ MPa}$$

$$f_{vsl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsl}/I_{rv} = 6.701 \text{ MPa}$$

(6) 온도차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P_1 = E_s \cdot \epsilon_t \cdot A_c/n = 3262140 \text{ N}$$

$$M_{vt} = P_1 \cdot d_{vc} = 3091663297 \text{ N} \cdot \text{mm}$$

$$E_{rt} = E_s \cdot \epsilon_t = 25.200 \text{ MPa}$$

$$f_{rut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vru}/I_{rv} - E_s \cdot \epsilon_t = -5.626 \text{ MPa}$$

$$f_{rlt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vrl}/I_{rv} - E_s \cdot \epsilon_t = -5.803 \text{ MPa}$$

$$f_{sut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsu}/I_{rv} = 19.168 \text{ MPa}$$

$$f_{slt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsl}/I_{rv} = 14.336 \text{ MPa}$$

(7) 전단 및 비틀림

$$u = (S_s + S_{sc} + S_v)/A_w + (M_{st}/(2 F T_w) + (M_{sct} + M_{vt})/(2 F_v T_w)) = 38.005 \text{ MPa} < u_a = 110 \text{ MPa} \quad 0.K!!!$$

(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 : $f_{ca} = 190 - 3.9 (b / (t_l \cdot i \cdot n) - 24) = 209.736$

$$\frac{b}{49 \cdot i \cdot n} > t_l \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.208 \text{ mm}$$

인 경우 : $f_{ca} = 220000 \times \{ (t_l \cdot i \cdot n) / b \} = 613.325 \text{ MPa}$

사용 $t_l = 22.0 \text{ mm}$

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	-71.005	64.630	190.000	190.000
1+2+3	-62.798	-58.819	160.000	-124.652	120.074	190.000	190.000
1+2+3+4	-67.960	-63.925	160.000	-129.684	116.591	190.000	190.000
1+2+3+4+5	-57.644	-53.730	160.000	-119.648	123.291	190.000	190.000
1+2+3+4+5+6	-63.270	-59.533	184.000	-100.479	137.627	218.500	218.500
1+2+3+4+5-6	-52.017	-47.928	184.000	-138.816	108.956	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)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{-129.684}{190.000} \right)^2 + \left(\frac{38.005}{110.000} \right)^2 \\ &= 0.466 + 0.119 = 0.585 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(하 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{123.291}{190.000} \right)^2 + \left(\frac{38.005}{110.000} \right)^2 \\ &= 0.421 + 0.119 = 0.540 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(10) 판의 최소두께 검토

인장(상부)플랜지 (☞ 도.설.기 3.8.3.1)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 20 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = 10 \text{ mm} \leq t = 22 \text{ mm} \quad \mathbf{0.K.} \quad (\text{합성형 스테드 설치})$$

압축(하부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 22 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 22 \text{ mm} \quad \mathbf{0.K!!!}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 64.630)} = 1.715 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = b / (219 \times 1.175) = 10.5 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 137.627)} = 1.175 < 1.2 \Rightarrow 1.175$$

(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

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vru} = -17.249 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -62.798 - -17.249 = -45.549 \text{ MPa}$$

$$\Sigma f = 1.3 \times -17.249 + 2.15 \times -45.549 + (-5.162) + (10.316) + (-5.626) \\ = -120.826 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times -17.249 + 2.15 \times -45.549 + (-5.626) \\ = -125.980 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = -71.005 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsu} = -14.736 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -124.652 - -71.005 - -14.736 = -38.911 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-71.005 + -14.736) + 2.15 \times -38.911 + (-5.032) + (10.036) + (-19.168) \\ = -209.286 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (-71.005 + -14.736) + 2.15 \times -38.911 + (-19.168) \\ = -214.290 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = 64.630 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsl} = 15.229 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 120.074 - 64.63 - 15.229 = 40.214 \text{ MPa}$$

$$\Sigma f = 1.3 \times (64.63 + 15.229) + 2.15 \times 40.214 + (-3.483) + (6.701) + (14.336) \\ = 207.831 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

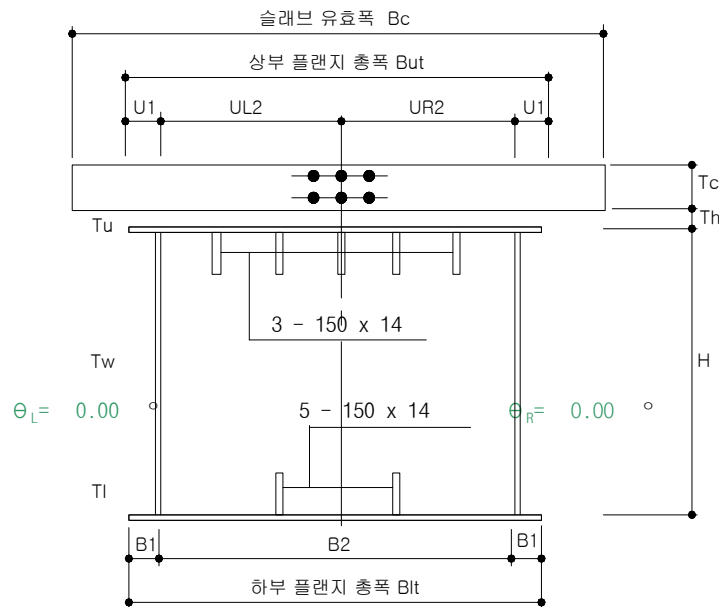
$$\Sigma f = 1.3 \times (64.63 + 15.229) + 2.15 \times 40.214 + (14.336) \\ = 204.614 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	-120.826	400.000	0.K!!!	3.31
	크리프, 건조수축제외시	-125.980	400.000	0.K!!!	3.17
상부플랜지	크리프, 건조수축 포함시	-209.286	315.000	0.K!!!	1.50
	크리프, 건조수축제외시	-214.290	315.000	0.K!!!	1.46
하부플랜지	크리프, 건조수축 포함시	207.831	315.000	0.K!!!	1.51
	크리프, 건조수축제외시	204.614	315.000	0.K!!!	1.53

5-11. 6경간 최대 부모멘트 단면검토(G1)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.700 m

Bc = 5.178 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 = 0.200 m

Th = 0.100 m

Tu = 0.030 m

Tl = 0.032 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	-20278.140
Msc : 합성후 고정하중에 의한 모멘트	kN · m	-4923.770
Mv : (활하중 + 지점침하)에 의한 모멘트	kN · m	-9066.297
Ss : 합성전 고정하중에 의한 전단력	kN	-1764.560
Ssc : 합성후 고정하중에 의한 전단력	kN	-412.210
Sv : (활하중 + 지점침하)에 의한 전단력	kN	-895.392
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-0.350
Msc : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-11.290
Mvt : (활하중 + 지점침하)에 의한 비틀림모멘트	kN · m	-898.338
t _{cu} , t _{cl} : 교축방향 철근의 피복두께	mm	50 , 50

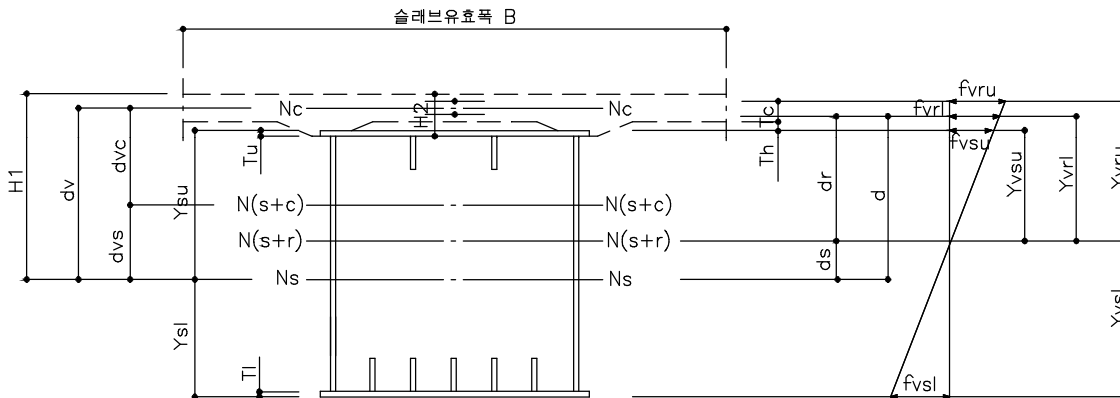
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	30.0	72960	1365.00	99590400	135940896000	5472000
3 - UPPER RIB	14.0	150.0	6300	1275.00	8032500	10241437500	11812500
1 - L_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
5 - LOWER RIB	14.0	150.0	10500	-1275.00	-13387500	17069062500	19687500
1 - LOWER FLANGE	2432.0	32.0	77824	-1366.00	-106307584	145216159744	6640981
강단면 합계			232384		-12072184	308467555744	39409612981
UPPER RE-BAR	-	-	4269.90	1600.00	6831840	10930944000	-
LOWER RE-BAR	-	-	6255.90	1500.00	9383850	14075775000	-
RE-BAR 합계			10526		16215690	25006719000	-
1 - RC SLAB	5178.0	200.0	1035600	1550.00	1605180000	2488029000000	3452000000

* $A_s = 232384 \text{ mm}^2$, $A_c = 1035600 \text{ mm}^2$, $A_r = 10526 \text{ mm}^2$

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = 308467555744 + 39409612981 = 347877168725 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -12072184 / 232384 = -51.949 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = 347877168725 - 232384 \times (-51.949)^2 = 347250027328 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2700.0 / 2 + 30.0 - (-51.949) = 1431.949 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1431.949 - 2762.000 = -1330.051 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + T_w) \cdot (H + T_u/2 + T_l/2) = 6860272.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = -83.621 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = 77.670 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot T_w) = 27.233 \text{ MPa}$$

(2) 합 성 후

$$\begin{aligned}A_v &= A_s + A_r = 242910 \text{ mm}^2 \\d &= Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1592.515 \text{ mm} \\d_r &= d \cdot A_s / (A_s + A_r) = 1523.508 \text{ mm} \\d_s &= d - d_r = 69.007 \text{ mm} \\Y_{vru} &= d_r + (T_c - t_{cu} - t_{cl}) \cdot A_{rl}/A_r = 1582.942 \text{ mm} \\Y_{vrl} &= d_r - (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1482.942 \text{ mm} \\Y_{vsu} &= Y_{vrl} - t_{cl} - T_h + T_u = 1362.942 \text{ mm} \\Y_{vsl} &= Y_{vsu} - (H + T_u + T_l) = -1399.058 \text{ mm} \\I_{rv} &= I_s + A_s \cdot d_s^2 + A_r \cdot d_r^2 = 372787830935 \text{ mm}^4 \\F_v &= b \cdot h_v = ((UL2 + UR2 + B2) / 2 + T_w) \cdot (H + (T_u + T_c/n)/2 + T_l/2) = 6891672.0 \text{ mm}^2 \\f_{vru} &= M_{sc} \cdot Y_{vru}/I_{rv} = -20.907 \text{ MPa} \\f_{vrl} &= M_{sc} \cdot Y_{vrl}/I_{rv} = -19.587 \text{ MPa} \\f_{vsu} &= M_{sc} \cdot Y_{vsu}/I_{rv} = -18.002 \text{ MPa} \\f_{vsl} &= M_{sc} \cdot Y_{vsl}/I_{rv} = 18.479 \text{ MPa} \\u &= S_{sc} / A(\text{Web}) + M_{sct} / (2 \cdot F_v \cdot T_w) = 6.430 \text{ MPa}\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}f_{vru} &= M_v \cdot Y_{vru}/I_{rv} = -38.498 \text{ MPa} \\f_{vrl} &= M_v \cdot Y_{vrl}/I_{rv} = -36.066 \text{ MPa} \\f_{vsu} &= M_v \cdot Y_{vsu}/I_{rv} = -33.147 \text{ MPa} \\f_{vsl} &= M_v \cdot Y_{vsl}/I_{rv} = 34.025 \text{ MPa} \\u &= S_v / A(\text{Web}) + M_{vt} / (2 \cdot F_v \cdot T_w) = 19.249 \text{ MPa}\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}A_{vc} &= A_s + A_c/n = 361834.000 \text{ mm}^2 \\d_v &= Y_{su} - T_u + T_h + T_c/2 = 1601.949 \text{ mm} \\d_{vc} &= d_v \cdot A_s / (A_c/n + A_s) = 1028.835 \text{ mm} \\d_{vs} &= d_v - d_{vc} = 573.115 \text{ mm} \\n_1 &= n \cdot (1 + \phi_1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\A_{v1} &= A_s + A_c/n_1 = 297109.000 \text{ mm}^2 \quad \# \text{ 2차 부정정력으로 인한 영향 고려} \\d_{c1} &= d_v \cdot A_s / (A_c/n_1 + A_s) = 1252.966 \text{ mm} \quad K = -0.300 \\d_{s1} &= d_v - d_{c1} = 348.984 \text{ mm} \\I_{cv} &= I_s + I_c/n + A_s \cdot d_{vs}^2 + A_c/n \cdot d_{vc}^2 = 561033387363.6 \text{ mm}^4 \\N_c &= M_{sc} \cdot d_{vc} \cdot A_c / (n \cdot I_{cv}) = -1168844 \text{ N} \\P\phi &= N_c \cdot 2 \cdot \phi_1 / (2 + \phi_1) = -1168844 \text{ N} \\M\phi &= P\phi \cdot d_{c1} = -1464521998 \text{ N} \cdot \text{mm} \\E_{c1} &= E_c / (1 + \phi_1 / 2) = 13351 \text{ MPa} \\f_{vru1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vru}/I_{rv} = -2.946 \text{ MPa} \\f_{vrl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vrl}/I_{rv} = -3.064 \text{ MPa} \\f_{vsu1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsu} / I_{rv} = -3.206 \text{ MPa} \\f_{vsl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsl} / I_{rv} = -6.461 \text{ MPa}\end{aligned}$$

(5) 건조수축

$$n_2 = n \cdot (1 + \phi_2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$A_{v2} = A_s + A_c/n_2 = 275534.000 \text{ mm}^2$$

$$d_{c2} = d_v \cdot A_s / (A_c/n_2 + A_s) = 1351.076 \text{ mm}$$

$$d_{s2} = d_v - d_{c2} = 250.873 \text{ mm}$$

$$P_2 = E_s \cdot \epsilon_s \cdot A_c/n_2 = 1631070 \text{ N}$$

$$M_{v2} = P_2 \cdot d_{c2} = 2203699587 \text{ N} \cdot \text{mm}$$

$$f_{vru2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vru}/I_{rv} = 3.907 \text{ MPa}$$

$$f_{vrl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vrl}/I_{rv} = 4.085 \text{ MPa}$$

$$f_{vsu2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsu}/I_{rv} = 4.298 \text{ MPa}$$

$$f_{vsl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsl}/I_{rv} = 9.196 \text{ MPa}$$

(6) 온도차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P_1 = E_s \cdot \epsilon_t \cdot A_c/n = 3262140 \text{ N}$$

$$M_{vt} = P_1 \cdot d_{vc} = 3356202911 \text{ N} \cdot \text{mm}$$

$$E_{rt} = E_s \cdot \epsilon_t = 25.200 \text{ MPa}$$

$$f_{rut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vru}/I_{rv} - E_s \cdot \epsilon_t = -16.046 \text{ MPa}$$

$$f_{rlt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vrl}/I_{rv} - E_s \cdot \epsilon_t = -15.776 \text{ MPa}$$

$$f_{sut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsu}/I_{rv} = 9.748 \text{ MPa}$$

$$f_{slt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsl}/I_{rv} = 17.208 \text{ MPa}$$

(7) 전단 및 비틀림

$$u = (S_s + S_{sc} + S_v)/A_w + (M_{st}/(2 F T_w) + (M_{sct} + M_{vt})/(2 F_v T_w)) = 52.912 \text{ MPa} < u_a = 110 \text{ MPa} \quad 0.K!!!$$

(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 : $f_{ca} = 190 - 3.9 (b / (t_l \cdot i \cdot n) - 24) = 232.819$

$$\frac{b}{49 \cdot i \cdot n} > t_l \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.208 \text{ mm}$$

인 경우 : $f_{ca} = 220000 \times \{ (t_l \cdot i \cdot n) / b \} = 1297.613 \text{ MPa}$

사용 $t_l = 32.0 \text{ mm}$

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	-83.621	77.670	190.000	190.000
1+2+3	-59.405	-55.652	160.000	-134.769	130.174	190.000	190.000
1+2+3+4	-62.351	-58.716	160.000	-137.975	123.714	190.000	190.000
1+2+3+4+5	-58.444	-54.631	160.000	-133.677	132.909	190.000	190.000
1+2+3+4+5+6	-74.490	-70.407	184.000	-123.929	150.118	218.500	218.500
1+2+3+4+5-6	-42.398	-38.856	184.000	-143.426	115.701	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)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{-137.975}{190.000} \right)^2 + \left(\frac{52.912}{110.000} \right)^2 \\ &= 0.527 + 0.231 = 0.759 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(하 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{132.909}{190.000} \right)^2 + \left(\frac{52.912}{110.000} \right)^2 \\ &= 0.489 + 0.231 = 0.721 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(10) 판의 최소두께 검토

인장(상부)플랜지 (☞ 도.설.기 3.8.3.1)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 30 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = 10 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K.} \quad (\text{합성형 스테드 설치})$$

압축(하부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K!!!}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 77.670)} = 1.564 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = b / (219 \times 1.125) = 11.0 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 150.118)} = 1.125 < 1.2 \Rightarrow 1.125$$

(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

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vru} = -20.907 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -59.405 - 20.907 = -38.498 \text{ MPa}$$

$$\Sigma f = 1.3 \times -20.907 + 2.15 \times -38.498 + (-2.946) + (3.907) + (-16.046) \\ = -125.034 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times -20.907 + 2.15 \times -38.498 + (-16.046) \\ = -125.995 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = -83.621 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsu} = -18.002 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -134.769 - 83.621 - 18.002 = -33.147 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-83.621 + -18.002) + 2.15 \times -33.147 + (-3.206) + (4.298) + (-9.748) \\ = -212.031 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (-83.621 + -18.002) + 2.15 \times -33.147 + (-9.748) \\ = -213.123 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = 77.670 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsl} = 18.479 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 130.174 - 77.67 - 18.479 = 34.026 \text{ MPa}$$

$$\Sigma f = 1.3 \times (77.67 + 18.479) + 2.15 \times 34.026 + (-6.461) + (9.196) + (17.208) \\ = 218.092 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

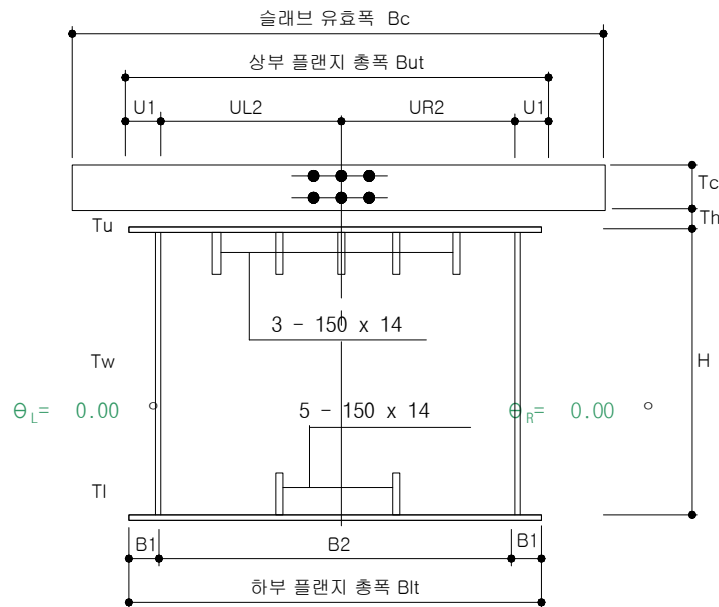
$$\Sigma f = 1.3 \times (77.67 + 18.479) + 2.15 \times 34.026 + (17.208) \\ = 215.356 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	-125.034	400.000	0.K!!!	3.19
	크리프, 건조수축제외시	-125.995	400.000	0.K!!!	3.17
상부플랜지	크리프, 건조수축 포함시	-212.031	315.000	0.K!!!	1.48
	크리프, 건조수축제외시	-213.123	315.000	0.K!!!	1.47
하부플랜지	크리프, 건조수축 포함시	218.092	315.000	0.K!!!	1.44
	크리프, 건조수축제외시	215.356	315.000	0.K!!!	1.46

5-12. 4경간 최대 부모멘트 단면검토(G2)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.700 m

Bc = 5.170 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 = 0.200 m

Th = 0.100 m

Tu = 0.030 m

TI = 0.032 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	-20230.380
Msc : 합성후 고정하중에 의한 모멘트	kN · m	-5676.430
Mv : (활하중 + 지점침하)에 의한 모멘트	kN · m	-10834.955
Ss : 합성전 고정하중에 의한 전단력	kN	-1762.800
Ssc : 합성후 고정하중에 의한 전단력	kN	-497.160
Sv : (활하중 + 지점침하)에 의한 전단력	kN	-1053.081
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	0.020
Mscst : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-36.820
Mvt : (활하중 + 지점침하)에 의한 비틀림모멘트	kN · m	-795.578
tcu,tcl : 교축방향 철근의 피복두께	mm	50 , 50

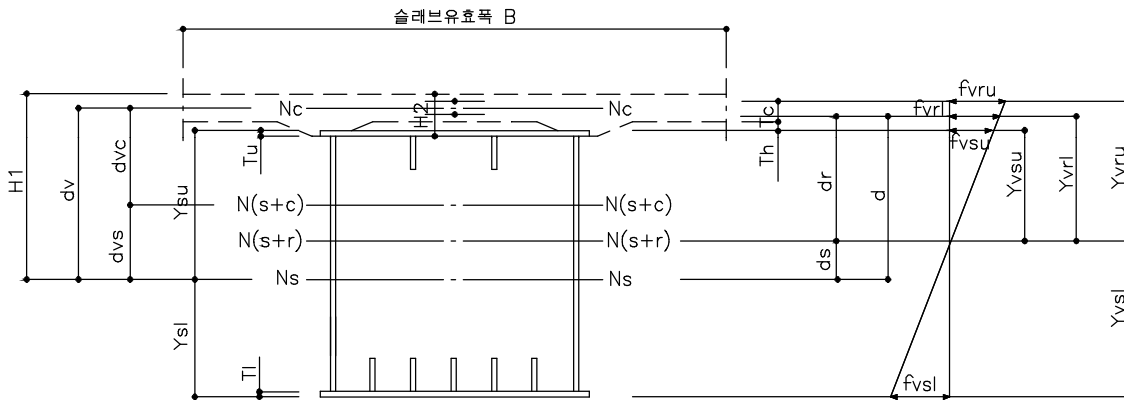
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	30.0	72960	1365.00	99590400	135940896000	5472000
3 - UPPER RIB	14.0	150.0	6300	1275.00	8032500	10241437500	11812500
1 - L_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
5 - LOWER RIB	14.0	150.0	10500	-1275.00	-13387500	17069062500	19687500
1 - LOWER FLANGE	2432.0	32.0	77824	-1366.00	-106307584	145216159744	6640981
강단면 합계			232384		-12072184	308467555744	39409612981
UPPER RE-BAR	-	-	3773.40	1600.00	6037440	9659904000	-
LOWER RE-BAR	-	-	6752.40	1500.00	10128600	15192900000	-
RE-BAR 합계			10526		16166040	24852804000	-
1 - RC SLAB	5170.0	200.0	1034000	1550.00	1602700000	2484185000000	3446666667

* $A_s = 232384 \text{ mm}^2$, $A_c = 1034000 \text{ mm}^2$, $A_r = 10526 \text{ mm}^2$

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = 308467555744 + 39409612981 = 347877168725 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -12072184 / 232384 = -51.949 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = 347877168725 - 232384 \times (-51.949)^2 = 347250027328 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2700.0 / 2 + 30.0 - (-51.949) = 1431.949 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1431.949 - 2762.000 = -1330.051 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + T_w) \cdot (H + T_u/2 + T_l/2) = 6860272.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = -83.424 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = 77.487 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot T_w) = 27.204 \text{ MPa}$$

(2) 합 성 후

$$\begin{aligned}A_v &= A_s + A_r = 242910 \text{ mm}^2 \\d &= Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1587.798 \text{ mm} \\d_r &= d \cdot A_s / (A_s + A_r) = 1518.996 \text{ mm} \\d_s &= d - d_r = 68.803 \text{ mm} \\Y_{vru} &= d_r + (T_c - t_{cu} - t_{cl}) \cdot A_{rl}/A_r = 1583.147 \text{ mm} \\Y_{vrl} &= d_r - (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1483.147 \text{ mm} \\Y_{vsu} &= Y_{vrl} - t_{cl} - T_h + T_u = 1363.147 \text{ mm} \\Y_{vsl} &= Y_{vsu} - (H + T_u + T_l) = -1398.853 \text{ mm} \\I_{rv} &= I_s + A_s \cdot d_s^2 + A_r \cdot d_r^2 = 372636770616 \text{ mm}^4 \\F_v &= b \cdot h_v = ((UL2 + UR2 + B2) / 2 + T_w) \cdot (H + (T_u + T_c/n)/2 + T_l/2) = 6891672.0 \text{ mm}^2 \\f_{vru} &= M_{sc} \cdot Y_{vru}/I_{rv} = -24.116 \text{ MPa} \\f_{vrl} &= M_{sc} \cdot Y_{vrl}/I_{rv} = -22.593 \text{ MPa} \\f_{vsu} &= M_{sc} \cdot Y_{vsu}/I_{rv} = -20.765 \text{ MPa} \\f_{vsl} &= M_{sc} \cdot Y_{vsl}/I_{rv} = 21.309 \text{ MPa} \\u &= S_{sc} / A(\text{Web}) + M_{sct} / (2 \cdot F_v \cdot T_w) = 7.895 \text{ MPa}\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}f_{vru} &= M_v \cdot Y_{vru}/I_{rv} = -46.032 \text{ MPa} \\f_{vrl} &= M_v \cdot Y_{vrl}/I_{rv} = -43.125 \text{ MPa} \\f_{vsu} &= M_v \cdot Y_{vsu}/I_{rv} = -39.635 \text{ MPa} \\f_{vsl} &= M_v \cdot Y_{vsl}/I_{rv} = 40.674 \text{ MPa} \\u &= S_v / A(\text{Web}) + M_{vt} / (2 \cdot F_v \cdot T_w) = 21.061 \text{ MPa}\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}A_{vc} &= A_s + A_c/n = 361634.000 \text{ mm}^2 \\d_v &= Y_{su} - T_u + T_h + T_c/2 = 1601.949 \text{ mm} \\d_{vc} &= d_v \cdot A_s / (A_c/n + A_s) = 1029.404 \text{ mm} \\d_{vs} &= d_v - d_{vc} = 572.546 \text{ mm} \\n_1 &= n \cdot (1 + \phi_1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\A_{v1} &= A_s + A_c/n_1 = 297009.000 \text{ mm}^2 \quad \# \text{ 2차 부정정력으로 인한 영향 고려} \\d_{c1} &= d_v \cdot A_s / (A_c/n_1 + A_s) = 1253.388 \text{ mm} \quad K = -0.300 \\d_{s1} &= d_v - d_{c1} = 348.562 \text{ mm} \\I_{cv} &= I_s + I_c/n + A_s \cdot d_{vs}^2 + A_c/n \cdot d_{vc}^2 = 560820903438.7 \text{ mm}^4 \\N_c &= M_{sc} \cdot d_{vc} \cdot A_c/(n \cdot I_{cv}) = -1346689 \text{ N} \\P\phi &= N_c \cdot 2 \cdot \phi_1 / (2 + \phi_1) = -1346689 \text{ N} \\M\phi &= P\phi \cdot d_{c1} = -1687923485 \text{ N} \cdot \text{mm} \\E_{c1} &= E_c / (1 + \phi_1 / 2) = 13351 \text{ MPa} \\f_{vru1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vru}/I_{rv} = -3.393 \text{ MPa} \\f_{vrl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vrl}/I_{rv} = -3.529 \text{ MPa} \\f_{vsu1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsu} / I_{rv} = -3.692 \text{ MPa} \\f_{vsl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsl} / I_{rv} = -7.445 \text{ MPa}\end{aligned}$$

(5) 건조수축

$$n_2 = n \cdot (1 + \phi_2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$A_{v2} = A_s + A_c/n_2 = 275467.333 \text{ mm}^2$$

$$d_{c2} = d_v \cdot A_s / (A_c/n_2 + A_s) = 1351.403 \text{ mm}$$

$$d_{s2} = d_v - d_{c2} = 250.546 \text{ mm}$$

$$P_2 = E_s \cdot \epsilon_s \cdot A_c/n_2 = 1628550 \text{ N}$$

$$M_{v2} = P_2 \cdot d_{c2} = 2200827375 \text{ N} \cdot \text{mm}$$

$$f_{vru2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vru}/I_{rv} = 3.899 \text{ MPa}$$

$$f_{vrl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vrl}/I_{rv} = 4.076 \text{ MPa}$$

$$f_{vsu2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsu}/I_{rv} = 4.289 \text{ MPa}$$

$$f_{vsl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsl}/I_{rv} = 9.183 \text{ MPa}$$

(6) 온도차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P_1 = E_s \cdot \epsilon_t \cdot A_c/n = 3257100 \text{ N}$$

$$M_{vt} = P_1 \cdot d_{vc} = 3352870848 \text{ N} \cdot \text{mm}$$

$$E_{rt} = E_s \cdot \epsilon_t = 25.200 \text{ MPa}$$

$$f_{rut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vru}/I_{rv} - E_s \cdot \epsilon_t = -16.065 \text{ MPa}$$

$$f_{rllt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vrl}/I_{rv} - E_s \cdot \epsilon_t = -15.795 \text{ MPa}$$

$$f_{sut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsu}/I_{rv} = 9.729 \text{ MPa}$$

$$f_{slt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsl}/I_{rv} = 17.185 \text{ MPa}$$

(7) 전단 및 비틀림

$$u = (S_s + S_{sc} + S_v)/A_w + (M_{st}/(2 F T_w) + (M_{sct} + M_{vt})/(2 F_v T_w)) = 56.160 \text{ MPa} < u_a = 110 \text{ MPa} \quad 0.K!!!$$

(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 : $f_{ca} = 190 - 3.9 (b / (t_l \cdot i \cdot n) - 24) = 232.819$

$$\frac{b}{49 \cdot i \cdot n} > t_l \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.208 \text{ mm}$$

인 경우 : $f_{ca} = 220000 \times \{ (t_l \cdot i \cdot n) / b \} = 1297.613 \text{ MPa}$

사용 $t_l = 32.0 \text{ mm}$

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	-83.424	77.487	190.000	190.000
1+2+3	-70.149	-65.718	160.000	-143.824	139.470	190.000	190.000
1+2+3+4	-73.541	-69.246	160.000	-147.516	132.025	190.000	190.000
1+2+3+4+5	-69.642	-65.170	160.000	-143.227	141.208	190.000	190.000
1+2+3+4+5+6	-85.707	-80.964	184.000	-133.498	158.392	218.500	218.500
1+2+3+4+5-6	-53.577	-49.375	184.000	-152.956	124.023	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)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{-147.516}{190.000} \right)^2 + \left(\frac{56.160}{110.000} \right)^2 \\ &= 0.603 + 0.261 = 0.863 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(하 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{141.208}{190.000} \right)^2 + \left(\frac{56.160}{110.000} \right)^2 \\ &= 0.552 + 0.261 = 0.813 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(10) 판의 최소두께 검토

인장(상부)플랜지 (☞ 도.설.기 3.8.3.1)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 30 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = 10 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K.} \quad (\text{합성형 스테드 설치})$$

압축(하부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K!!!}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 77.487)} = 1.566 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = b / (219 \times 1.095) = 11.3 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 158.392)} = 1.095 < 1.2 \Rightarrow 1.095$$

(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

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vru} = -24.116 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -70.149 - 24.116 = -46.032 \text{ MPa}$$

$$\Sigma f = 1.3 \times -24.116 + 2.15 \times -46.032 + (-3.393) + (3.899) + (-16.065) \\ = -145.879 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times -24.116 + 2.15 \times -46.032 + (-16.065) \\ = -146.385 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = -83.424 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsu} = -20.765 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -143.824 - 83.424 - 20.765 = -39.635 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-83.424 + -20.765) + 2.15 \times -39.635 + (-3.692) + (4.289) + (-9.729) \\ = -229.793 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (-83.424 + -20.765) + 2.15 \times -39.635 + (-9.729) \\ = -230.390 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = 77.487 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsl} = 21.309 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 139.47 - 77.487 - 21.309 = 40.674 \text{ MPa}$$

$$\Sigma f = 1.3 \times (77.487 + 21.309) + 2.15 \times 40.674 + (-7.445) + (9.183) + (17.185) \\ = 234.806 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

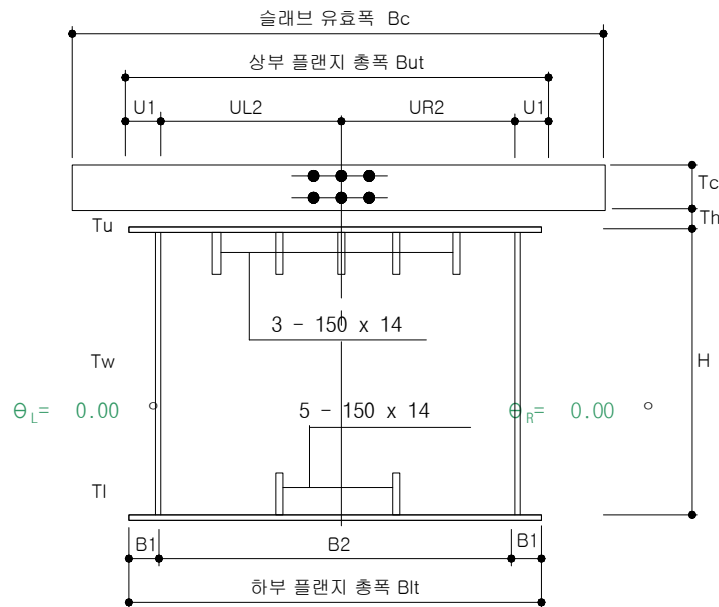
$$\Sigma f = 1.3 \times (77.487 + 21.309) + 2.15 \times 40.674 + (17.185) \\ = 233.068 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	-145.879	400.000	0.K!!!	2.74
	크리프, 건조수축제외시	-146.385	400.000	0.K!!!	2.73
상부플랜지	크리프, 건조수축 포함시	-229.793	315.000	0.K!!!	1.37
	크리프, 건조수축제외시	-230.390	315.000	0.K!!!	1.36
하부플랜지	크리프, 건조수축 포함시	234.806	315.000	0.K!!!	1.34
	크리프, 건조수축제외시	233.068	315.000	0.K!!!	1.35

5-13. 5경간 최대 부모멘트 단면검토(G2)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.700 m

Bc = 5.170 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 = 0.200 m

Th = 0.100 m

Tu = 0.020 m

Tl = 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 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	-12600.680
Msc : 합성후 고정하중에 의한 모멘트	kN · m	-3682.950
Mv : (활하중 + 지점침하)에 의한 모멘트	kN · m	-9597.045
Ss : 합성전 고정하중에 의한 전단력	kN	1159.020
Ssc : 합성후 고정하중에 의한 전단력	kN	338.350
Sv : (활하중 + 지점침하)에 의한 전단력	kN	824.511
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-0.200
Mscst : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-21.400
Mvt : (활하중 + 지점침하)에 의한 비틀림모멘트	kN · m	-721.838
tcu,tcl : 교축방향 철근의 피복두께	mm	50 , 50

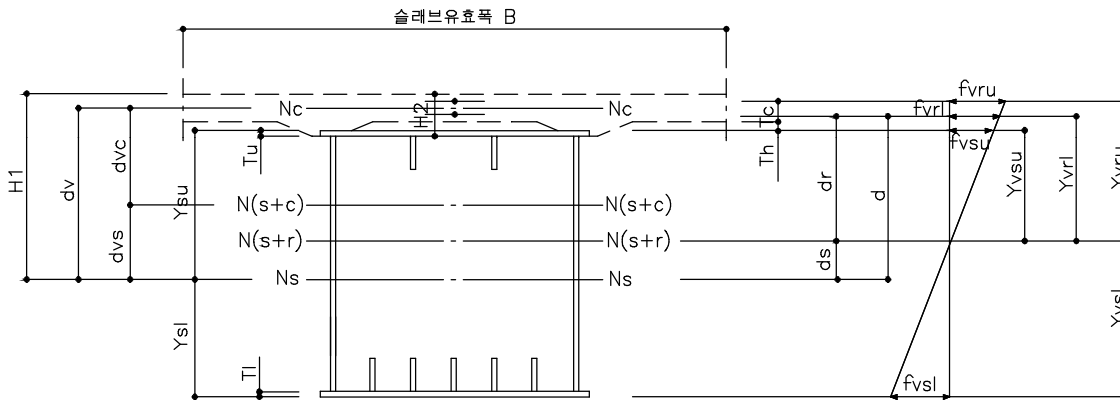
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	20.0	48640	1360.00	66150400	89964544000	1621333
3 - UPPER RIB	14.0	150.0	6300	1275.00	8032500	10241437500	11812500
1 - L_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
5 - LOWER RIB	14.0	150.0	10500	-1275.00	-13387500	17069062500	19687500
1 - LOWER FLANGE	2432.0	22.0	53504	-1361.00	-72818944	99106582784	2157995
강단면 합계			183744		-12023544	216381626784	39401279328
UPPER RE-BAR	-	-	3773.40	1600.00	6037440	9659904000	-
LOWER RE-BAR	-	-	6752.40	1500.00	10128600	15192900000	-
RE-BAR 합계			10526		16166040	24852804000	-
1 - RC SLAB	5170.0	200.0	1034000	1550.00	1602700000	2484185000000	3446666667

* $A_s = 183744 \text{ mm}^2$, $A_c = 1034000 \text{ mm}^2$, $A_r = 10526 \text{ mm}^2$

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = 216381626784 + 39401279328 = 255782906112 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -12023544 / 183744 = -65.436 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = 255782906112 - 183744 \times (-65.436)^2 = 254996128801 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2700.0 / 2 + 20.0 - (-65.436) = 1435.436 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1435.436 - 2742.000 = -1306.564 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6835152.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = -70.932 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = 64.564 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 17.887 \text{ MPa}$$

(2) 합 성 후

$$\begin{aligned}A_v &= A_s + A_r = 194270 \text{ mm}^2 \\d &= Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1601.285 \text{ mm} \\d_r &= d \cdot A_s / (A_s + A_r) = 1514.526 \text{ mm} \\d_s &= d - d_r = 86.760 \text{ mm} \\Y_{vru} &= d_r + (T_c - t_{cu} - t_{cl}) \cdot A_{rl}/A_r = 1578.677 \text{ mm} \\Y_{vrl} &= d_r - (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1478.677 \text{ mm} \\Y_{vsu} &= Y_{vrl} - t_{cl} - T_h + T_u = 1348.677 \text{ mm} \\Y_{vsl} &= Y_{vsu} - (H + T_u + T_l) = -1393.323 \text{ mm} \\I_{rv} &= I_s + A_s \cdot d_s^2 + A_r \cdot d_r^2 = 280523171224 \text{ mm}^4 \\F_v &= b \cdot h_v = ((UL2 + UR2 + B2) / 2 + T_w) \cdot (H + (T_u + T_c/n)/2 + T_l/2) = 6866552.0 \text{ mm}^2 \\f_{vru} &= M_{sc} \cdot Y_{vru}/I_{rv} = -20.726 \text{ MPa} \\f_{vrl} &= M_{sc} \cdot Y_{vrl}/I_{rv} = -19.413 \text{ MPa} \\f_{vsu} &= M_{sc} \cdot Y_{vsu}/I_{rv} = -17.707 \text{ MPa} \\f_{vsl} &= M_{sc} \cdot Y_{vsl}/I_{rv} = 18.293 \text{ MPa} \\u &= S_{sc} / A(\text{Web}) + M_{sct} / (2 \cdot F_v \cdot T_w) = 5.351 \text{ MPa}\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}f_{vru} &= M_v \cdot Y_{vru}/I_{rv} = -54.008 \text{ MPa} \\f_{vrl} &= M_v \cdot Y_{vrl}/I_{rv} = -50.587 \text{ MPa} \\f_{vsu} &= M_v \cdot Y_{vsu}/I_{rv} = -46.140 \text{ MPa} \\f_{vsl} &= M_v \cdot Y_{vsl}/I_{rv} = 47.667 \text{ MPa} \\u &= S_v / A(\text{Web}) + M_{vt} / (2 \cdot F_v \cdot T_w) = 17.104 \text{ MPa}\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}A_{vc} &= A_s + A_c/n = 312994.000 \text{ mm}^2 \\d_v &= Y_{su} - T_u + T_h + T_c/2 = 1615.436 \text{ mm} \\d_{vc} &= d_v \cdot A_s / (A_c/n + A_s) = 948.346 \text{ mm} \\d_{vs} &= d_v - d_{vc} = 667.090 \text{ mm} \\n_1 &= n \cdot (1 + \phi_1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\A_{v1} &= A_s + A_c/n_1 = 248369.000 \text{ mm}^2 \quad \# \text{ 2차 부정정력으로 인한 영향 고려} \\d_{c1} &= d_v \cdot A_s / (A_c/n_1 + A_s) = 1195.104 \text{ mm} \quad K = 0.160 \\d_{s1} &= d_v - d_{c1} = 420.333 \text{ mm} \\I_{cv} &= I_s + I_c/n + A_s \cdot d_{vs}^2 + A_c/n \cdot d_{vc}^2 = 453437101432.7 \text{ mm}^4 \\N_c &= M_{sc} \cdot d_{vc} \cdot A_c/(n \cdot I_{cv}) = -995580 \text{ N} \\P\phi &= N_c \cdot 2 \cdot \phi_1 / (2 + \phi_1) = -995580 \text{ N} \\M\phi &= P\phi \cdot d_{c1} = -1189821953 \text{ N} \cdot \text{mm} \\E_{c1} &= E_c / (1 + \phi_1 / 2) = 13351 \text{ MPa} \\f_{vru1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vru}/I_{rv} = -6.196 \text{ MPa} \\f_{vrl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vrl}/I_{rv} = -6.128 \text{ MPa} \\f_{vsu1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsu} / I_{rv} = -6.040 \text{ MPa} \\f_{vsl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsl} / I_{rv} = -4.179 \text{ MPa}\end{aligned}$$

(5) 건조수축

$$n_2 = n \cdot (1 + \phi_2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$A_{v2} = A_s + A_c/n_2 = 226827.333 \text{ mm}^2$$

$$d_{c2} = d_v \cdot A_s / (A_c/n_2 + A_s) = 1308.602 \text{ mm}$$

$$d_{s2} = d_v - d_{c2} = 306.834 \text{ mm}$$

$$P_2 = E_s \cdot \epsilon_s \cdot A_c/n_2 = 1628550 \text{ N}$$

$$M_{v2} = P_2 \cdot d_{c2} = 2131124088 \text{ N} \cdot \text{mm}$$

$$f_{vru2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vru}/I_{rv} = 10.302 \text{ MPa}$$

$$f_{vrl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vrl}/I_{rv} = 10.180 \text{ MPa}$$

$$f_{vsu2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsu}/I_{rv} = 10.022 \text{ MPa}$$

$$f_{vsl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsl}/I_{rv} = 6.689 \text{ MPa}$$

(6) 온도차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P_1 = E_s \cdot \epsilon_t \cdot A_c/n = 3257100 \text{ N}$$

$$M_{vt} = P_1 \cdot d_{vc} = 3088859173 \text{ N} \cdot \text{mm}$$

$$E_{rt} = E_s \cdot \epsilon_t = 25.200 \text{ MPa}$$

$$f_{rut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vru}/I_{rv} - E_s \cdot \epsilon_t = -5.653 \text{ MPa}$$

$$f_{rlt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vrl}/I_{rv} - E_s \cdot \epsilon_t = -5.829 \text{ MPa}$$

$$f_{sut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsu}/I_{rv} = 19.142 \text{ MPa}$$

$$f_{slt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsl}/I_{rv} = 14.311 \text{ MPa}$$

(7) 전단 및 비틀림

$$u = (S_s + S_{sc} + S_v)/A_w + (M_{st}/(2 F T_w) + (M_{sct} + M_{vt})/(2 F_v T_w)) = 40.343 \text{ MPa} < u_a = 110 \text{ MPa} \quad \mathbf{0.K!!!}$$

(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 : $f_{ca} = 190 - 3.9 (b / (t_l \cdot i \cdot n) - 24) = 209.736$

$$\frac{b}{49 \cdot i \cdot n} > t_l \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.208 \text{ mm}$$

인 경우 : $f_{ca} = 220000 \times \{ (t_l \cdot i \cdot n) / b \} = 613.325 \text{ MPa}$

사용 $t_l = 22.0 \text{ mm}$

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	-70.932	64.564	190.000	190.000
1+2+3	-74.735	-70.001	160.000	-134.779	130.524	190.000	190.000
1+2+3+4	-80.931	-76.129	160.000	-140.819	126.345	190.000	190.000
1+2+3+4+5	-70.629	-65.949	160.000	-130.797	133.034	190.000	190.000
1+2+3+4+5+6	-76.282	-71.778	184.000	-111.655	147.345	218.500	218.500
1+2+3+4+5-6	-64.976	-60.120	184.000	-149.938	118.723	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)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{-140.819}{190.000} \right)^2 + \left(\frac{40.343}{110.000} \right)^2 \\ &= 0.549 + 0.135 = 0.684 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(하 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{133.034}{190.000} \right)^2 + \left(\frac{40.343}{110.000} \right)^2 \\ &= 0.490 + 0.135 = 0.625 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(10) 판의 최소두께 검토

인장(상부)플랜지 (도.설.기 3.8.3.1)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 20 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = 10 \text{ mm} \leq t = 22 \text{ mm} \quad \mathbf{0.K.} \quad (\text{합성형 스테드 설치})$$

압축(하부)플랜지 (도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 22 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 22 \text{ mm} \quad \mathbf{0.K!!!}$$

복부판 수평보강재 사용단수 1 단 (도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 64.564)} = 1.715 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = b / (219 \times 1.136) = 10.9 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 147.345)} = 1.136 < 1.2 \Rightarrow 1.136$$

(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

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vru} = -20.726 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -74.735 - 20.726 = -54.008 \text{ MPa}$$

$$\Sigma f = 1.3 \times -20.726 + 2.15 \times -54.008 + (-6.196) + (10.302) + (-5.653) = -144.609 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times -20.726 + 2.15 \times -54.008 + (-5.653) = -148.715 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = -70.932 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsu} = -17.707 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -134.779 - 70.932 - 17.707 = -46.140 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-70.932 + -17.707) + 2.15 \times -46.14 + (-6.04) + (10.022) + (-19.142) = -229.591 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (-70.932 + -17.707) + 2.15 \times -46.14 + (-19.142) = -233.574 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = 64.564 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsl} = 18.293 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 130.524 - 64.564 - 18.293 = 47.667 \text{ MPa}$$

$$\Sigma f = 1.3 \times (64.564 + 18.293) + 2.15 \times 47.667 + (-4.179) + (6.689) + (14.311) = 227.020 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

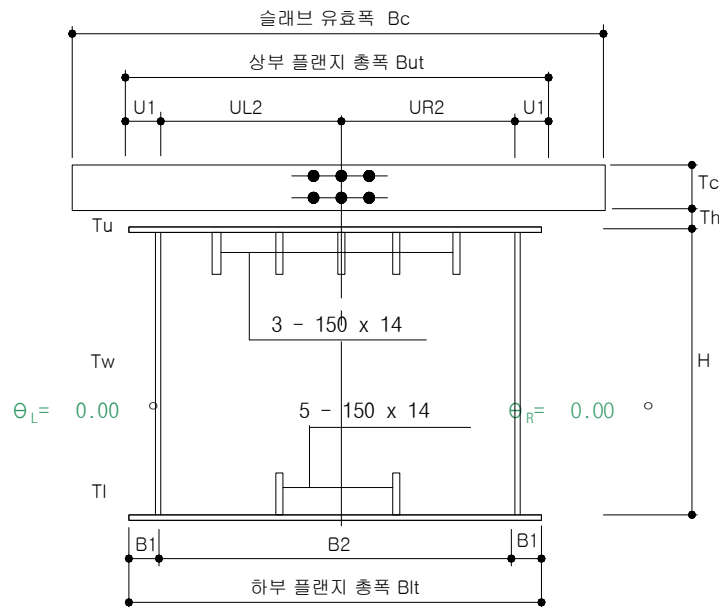
$$\Sigma f = 1.3 \times (64.564 + 18.293) + 2.15 \times 47.667 + (14.311) = 224.510 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	-144.609	400.000	0.K!!!	2.76
	크리프, 건조수축제외시	-148.715	400.000	0.K!!!	2.68
상부플랜지	크리프, 건조수축 포함시	-229.591	315.000	0.K!!!	1.37
	크리프, 건조수축제외시	-233.574	315.000	0.K!!!	1.34
하부플랜지	크리프, 건조수축 포함시	227.020	315.000	0.K!!!	1.38
	크리프, 건조수축제외시	224.510	315.000	0.K!!!	1.40

5-14. 6경간 최대 부모멘트 단면검토(G2)

1) 단면가정 및 설계조건



주부재사용강종 = SM490

H = 2.700 m

Bc = 5.170 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 = 0.200 m

Th = 0.100 m

Tu = 0.030 m

TI = 0.032 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 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	-20260.380
Msc : 합성후 고정하중에 의한 모멘트	kN · m	-5676.430
Mv : (활하중 + 지점침하)에 의한 모멘트	kN · m	-10834.945
Ss : 합성전 고정하중에 의한 전단력	kN	-1762.800
Ssc : 합성후 고정하중에 의한 전단력	kN	-497.160
Sv : (활하중 + 지점침하)에 의한 전단력	kN	-1053.081
Mst : 합성전 고정하중에 의한 비틀림모멘트	kN · m	-0.430
Mscst : 합성후 고정하중에 의한 비틀림모멘트	kN · m	-13.180
Mvt : (활하중 + 지점침하)에 의한 비틀림모멘트	kN · m	-763.938
tcu,tcl : 교축방향 철근의 피복두께	mm	50 , 50

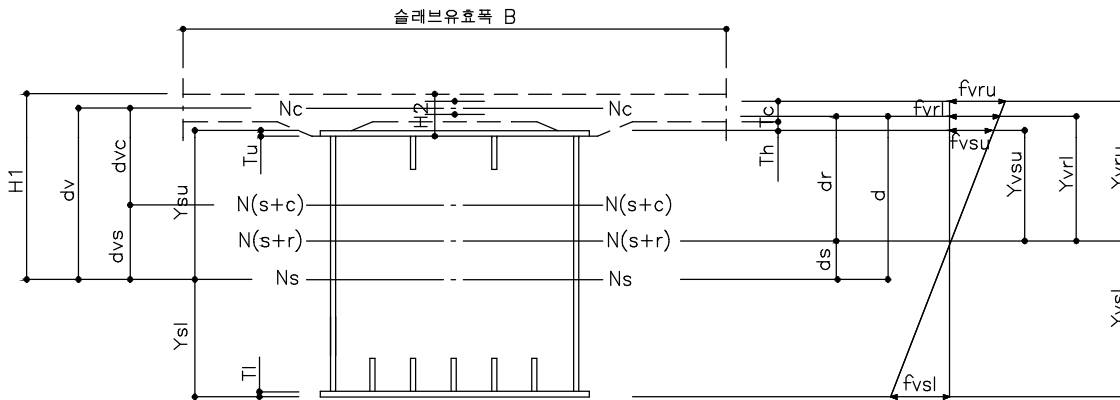
< 참고 > 합성전 고정하중 : 강재자중 + 콘크리트바닥판자중
합성후 고정하중 : 방호벽 + PAVEMENT자중

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	30.0	72960	1365.00	99590400	135940896000	5472000
3 - UPPER RIB	14.0	150.0	6300	1275.00	8032500	10241437500	11812500
1 - L_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
1 - R_WEB	12.0	2700.0	32400	0.00	0	0	19683000000
5 - LOWER RIB	14.0	150.0	10500	-1275.00	-13387500	17069062500	19687500
1 - LOWER FLANGE	2432.0	32.0	77824	-1366.00	-106307584	145216159744	6640981
강단면 합계			232384		-12072184	308467555744	39409612981
UPPER RE-BAR	-	-	3773.40	1600.00	6037440	9659904000	-
LOWER RE-BAR	-	-	6752.40	1500.00	10128600	15192900000	-
RE-BAR 합계			10526		16166040	24852804000	-
1 - RC SLAB	5170.0	200.0	1034000	1550.00	1602700000	2484185000000	3446666667

* $A_s = 232384 \text{ mm}^2$, $A_c = 1034000 \text{ mm}^2$, $A_r = 10526 \text{ mm}^2$

2) 응 력 검 토



(1) 합 성 전

$$I_s' = A_s \cdot Y^2 + \sum I_s = 308467555744 + 39409612981 = 347877168725 \text{ mm}^4$$

$$\delta s = \sum (A \cdot Y) / A_s = -12072184 / 232384 = -51.949 \text{ mm}$$

$$I_s = I_s' - A_s \cdot \delta s^2 = 347877168725 - 232384 \times (-51.949)^2 = 347250027328 \text{ mm}^4$$

$$Y_{su} = H/2 + T_u - \delta s = 2700.0 / 2 + 30.0 - (-51.949) = 1431.949 \text{ mm}$$

$$Y_{sl} = Y_{su} - (H + T_u + T_l) = 1431.949 - 2762.000 = -1330.051 \text{ mm}$$

$$F = b \cdot h = ((UL2 + UR2 + B2) / 2 + Tw) \cdot (H + Tu/2 + Tl/2) = 6860272.0 \text{ mm}^2$$

$$f_{su} = M_s \cdot Y_{su} / I_s = -83.547 \text{ MPa}$$

$$f_{sl} = M_s \cdot Y_{sl} / I_s = 77.602 \text{ MPa}$$

$$u = S_s / A(\text{Web}) + M_{st} / (2 \cdot F \cdot Tw) = 27.206 \text{ MPa}$$

(2) 합 성 후

$$\begin{aligned}A_v &= A_s + A_r = 242910 \text{ mm}^2 \\d &= Y_{su} - T_u + T_h + t_{cl} + (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1587.798 \text{ mm} \\d_r &= d \cdot A_s / (A_s + A_r) = 1518.996 \text{ mm} \\d_s &= d - d_r = 68.803 \text{ mm} \\Y_{vru} &= d_r + (T_c - t_{cu} - t_{cl}) \cdot A_{rl}/A_r = 1583.147 \text{ mm} \\Y_{vrl} &= d_r - (T_c - t_{cu} - t_{cl}) \cdot A_{ru}/A_r = 1483.147 \text{ mm} \\Y_{vsu} &= Y_{vrl} - t_{cl} - T_h + T_u = 1363.147 \text{ mm} \\Y_{vsl} &= Y_{vsu} - (H + T_u + T_l) = -1398.853 \text{ mm} \\I_{rv} &= I_s + A_s \cdot d_s^2 + A_r \cdot d_r^2 = 372636770616 \text{ mm}^4 \\F_v &= b \cdot h_v = ((UL2 + UR2 + B2) / 2 + T_w) \cdot (H + (T_u + T_c/n)/2 + T_l/2) = 6891672.0 \text{ mm}^2 \\f_{vru} &= M_{sc} \cdot Y_{vru}/I_{rv} = -24.116 \text{ MPa} \\f_{vrl} &= M_{sc} \cdot Y_{vrl}/I_{rv} = -22.593 \text{ MPa} \\f_{vsu} &= M_{sc} \cdot Y_{vsu}/I_{rv} = -20.765 \text{ MPa} \\f_{vsl} &= M_{sc} \cdot Y_{vsl}/I_{rv} = 21.309 \text{ MPa} \\u &= S_{sc} / A(\text{Web}) + M_{sct} / (2 \cdot F_v \cdot T_w) = 7.752 \text{ MPa}\end{aligned}$$

(3) 활 하 중

$$\begin{aligned}f_{vru} &= M_v \cdot Y_{vru}/I_{rv} = -46.032 \text{ MPa} \\f_{vrl} &= M_v \cdot Y_{vrl}/I_{rv} = -43.125 \text{ MPa} \\f_{vsu} &= M_v \cdot Y_{vsu}/I_{rv} = -39.635 \text{ MPa} \\f_{vsl} &= M_v \cdot Y_{vsl}/I_{rv} = 40.674 \text{ MPa} \\u &= S_v / A(\text{Web}) + M_{vt} / (2 \cdot F_v \cdot T_w) = 20.870 \text{ MPa}\end{aligned}$$

(4) 크 리 이 프

$$\begin{aligned}A_{vc} &= A_s + A_c/n = 361634.000 \text{ mm}^2 \\d_v &= Y_{su} - T_u + T_h + T_c/2 = 1601.949 \text{ mm} \\d_{vc} &= d_v \cdot A_s / (A_c/n + A_s) = 1029.404 \text{ mm} \\d_{vs} &= d_v - d_{vc} = 572.546 \text{ mm} \\n_1 &= n \cdot (1 + \phi_1 / 2) = 8 \times (1 + 2.0 / 2) = 16 \\A_{v1} &= A_s + A_c/n_1 = 297009.000 \text{ mm}^2 \quad \# \text{ 2차 부정정력으로 인한 영향 고려} \\d_{c1} &= d_v \cdot A_s / (A_c/n_1 + A_s) = 1253.388 \text{ mm} \quad K = -0.300 \\d_{s1} &= d_v - d_{c1} = 348.562 \text{ mm} \\I_{cv} &= I_s + I_c/n + A_s \cdot d_{vs}^2 + A_c/n \cdot d_{vc}^2 = 560820903438.7 \text{ mm}^4 \\N_c &= M_{sc} \cdot d_{vc} \cdot A_c/(n \cdot I_{cv}) = -1346689 \text{ N} \\P\phi &= N_c \cdot 2 \cdot \phi_1 / (2 + \phi_1) = -1346689 \text{ N} \\M\phi &= P\phi \cdot d_{c1} = -1687923485 \text{ N} \cdot \text{mm} \\E_{c1} &= E_c / (1 + \phi_1 / 2) = 13351 \text{ MPa} \\f_{vru1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vru}/I_{rv} = -3.393 \text{ MPa} \\f_{vrl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vrl}/I_{rv} = -3.529 \text{ MPa} \\f_{vsu1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsu} / I_{rv} = -3.692 \text{ MPa} \\f_{vsl1} &= P\phi / A_v + k \cdot M\phi \cdot Y_{vsl} / I_{rv} = -7.445 \text{ MPa}\end{aligned}$$

(5) 건조수축

$$n_2 = n \cdot (1 + \phi_2 / 2) = 8 \times (1 + 4.0 / 2) = 24$$

$$A_{v2} = A_s + A_c/n_2 = 275467.333 \text{ mm}^2$$

$$d_{c2} = d_v \cdot A_s / (A_c/n_2 + A_s) = 1351.403 \text{ mm}$$

$$d_{s2} = d_v - d_{c2} = 250.546 \text{ mm}$$

$$P_2 = E_s \cdot \epsilon_s \cdot A_c/n_2 = 1628550 \text{ N}$$

$$M_{v2} = P_2 \cdot d_{c2} = 2200827375 \text{ N} \cdot \text{mm}$$

$$f_{vru2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vru}/I_{rv} = 3.899 \text{ MPa}$$

$$f_{vrl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vrl}/I_{rv} = 4.076 \text{ MPa}$$

$$f_{vsu2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsu}/I_{rv} = 4.289 \text{ MPa}$$

$$f_{vsl2} = P_2/A_v + K \cdot M_{v2} \cdot Y_{vsl}/I_{rv} = 9.183 \text{ MPa}$$

(6) 온도차

$$\epsilon_t = \alpha \cdot t = 0.000012 \times 10 = 0.00012$$

$$P_1 = E_s \cdot \epsilon_t \cdot A_c/n = 3257100 \text{ N}$$

$$M_{vt} = P_1 \cdot d_{vc} = 3352870848 \text{ N} \cdot \text{mm}$$

$$E_{rt} = E_s \cdot \epsilon_t = 25.200 \text{ MPa}$$

$$f_{rut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vru}/I_{rv} - E_s \cdot \epsilon_t = -16.065 \text{ MPa}$$

$$f_{rlt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vrl}/I_{rv} - E_s \cdot \epsilon_t = -15.795 \text{ MPa}$$

$$f_{sut} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsu}/I_{rv} = 9.729 \text{ MPa}$$

$$f_{slt} = P_1/A_v + K \cdot M_{vt} \cdot Y_{vsl}/I_{rv} = 17.185 \text{ MPa}$$

(7) 전단 및 비틀림

$$u = (S_s + S_{sc} + S_v)/A_w + (M_{st}/(2 F T_w) + (M_{sct} + M_{vt})/(2 F_v T_w)) = 55.828 \text{ MPa} < u_a = 110 \text{ MPa} \quad \mathbf{0.K!!!}$$

(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 : $f_{ca} = 190 - 3.9 (b / (t_l \cdot i \cdot n) - 24) = 232.819$

$$\frac{b}{49 \cdot i \cdot n} > t_l \geq \frac{b}{80 \cdot i \cdot n} = \frac{2500}{80 \times 1.000 \times 6} = 5.208 \text{ mm}$$

인 경우 : $f_{ca} = 220000 \times \{ (t_l \cdot i \cdot n) / b \} = 1297.613 \text{ MPa}$

사용 $t_l = 32.0 \text{ mm}$

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	-83.547	77.602	190.000	190.000
1+2+3	-70.149	-65.718	160.000	-143.948	139.585	190.000	190.000
1+2+3+4	-73.541	-69.246	160.000	-147.639	132.140	190.000	190.000
1+2+3+4+5	-69.642	-65.170	160.000	-143.350	141.323	190.000	190.000
1+2+3+4+5+6	-85.707	-80.964	184.000	-133.621	158.507	218.500	218.500
1+2+3+4+5-6	-53.577	-49.375	184.000	-153.079	124.138	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)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{-147.639}{190.000} \right)^2 + \left(\frac{55.828}{110.000} \right)^2 \\ &= 0.604 + 0.258 = 0.861 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(하 연)

$$\begin{aligned} \left(\frac{f}{f_a} \right)^2 + \left(\frac{u}{u_a} \right)^2 &= \left(\frac{141.323}{190.000} \right)^2 + \left(\frac{55.828}{110.000} \right)^2 \\ &= 0.553 + 0.258 = 0.811 < 1.2 \quad \mathbf{O.K!!!} \end{aligned}$$

(10) 판의 최소두께 검토

인장(상부)플랜지 (☞ 도.설.기 3.8.3.1)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 30 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = 10 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K.} \quad (\text{합성형 스테드 설치})$$

압축(하부)플랜지 (☞ 도.설.기 3.4.2.2, 3.4.2.3 및 3.9.6)

$$t_{min} = \text{자유돌출폭} / 16 = 100 / 16 = 6.3 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K!!!}$$

$$t_{min} = b / (49 \cdot i \cdot n) = 2500 / (49 \times 1.00 \times 6) = 8.5 \text{ mm} \leq t = 32 \text{ mm} \quad \mathbf{0.K!!!}$$

복부판 수평보강재 사용단수 1 단 (☞ 도.설.기 3.8.4)

$$\text{합성전 } t_{min} = b / (219 \times 1.200) = 10.3 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 77.602)} = 1.565 > 1.2 \Rightarrow 1.200$$

$$\text{합성후 } t_{min} = b / (219 \times 1.095) = 11.3 \text{ mm} \leq t = 12 \text{ mm} \quad \mathbf{0.K!!!}$$

$$\text{여기서, } \sqrt{(f_{ca}/f_c)} = \sqrt{(190.0 / 158.507)} = 1.095 < 1.2 \Rightarrow 1.095$$

(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

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vru} = -24.116 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -70.149 - -24.116 = -46.032 \text{ MPa}$$

$$\Sigma f = 1.3 \times -24.116 + 2.15 \times -46.032 + (-3.393) + (3.899) + (-16.065) \\ = -145.879 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times -24.116 + 2.15 \times -46.032 + (-16.065) \\ = -146.385 \text{ MPa} < f_y = 400.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

② 강재주형 상판

$$\text{합성전 사하중 응력} = -83.547 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsu} = -20.765 \text{ MPa}$$

$$\text{합성후 활하중 응력} = -143.948 - -83.547 - -20.765 = -39.636 \text{ MPa}$$

$$\Sigma f = 1.3 \times (-83.547 + -20.765) + 2.15 \times -39.636 + (-3.692) + (4.289) + (-9.729) \\ = -229.954 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (-83.547 + -20.765) + 2.15 \times -39.636 + (-9.729) \\ = -230.552 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!} \quad (\text{크리프, 건조수축 제외시})$$

③ 강재주형 하판

$$\text{합성전 사하중 응력} = 77.602 \text{ MPa}$$

$$\text{합성후 사하중 응력} = M_{sc} / I_{rv} \times Y_{vsl} = 21.309 \text{ MPa}$$

$$\text{합성후 활하중 응력} = 139.585 - 77.602 - 21.309 = 40.674 \text{ MPa}$$

$$\Sigma f = 1.3 \times (77.602 + 21.309) + 2.15 \times 40.674 + (-7.445) + (9.183) + (17.185) \\ = 234.955 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 포함시})$$

$$\Sigma f = 1.3 \times (77.602 + 21.309) + 2.15 \times 40.674 + (17.185) \\ = 233.217 \text{ MPa} < f_y = 315.0 \text{ MPa} \quad \mathbf{0.K!!!} \quad (\text{크리프, 건조수축 제외시})$$

- 항복에 대한 안전도 검사 결과 집계

구분		작용응력	항복응력	검토결과	
바닥판 콘크리트	크리프, 건조수축 포함시	-145.879	400.000	0.K!!!	2.74
	크리프, 건조수축제외시	-146.385	400.000	0.K!!!	2.73
상부플랜지	크리프, 건조수축 포함시	-229.954	315.000	0.K!!!	1.36
	크리프, 건조수축제외시	-230.552	315.000	0.K!!!	1.36
하부플랜지	크리프, 건조수축 포함시	234.955	315.000	0.K!!!	1.34
	크리프, 건조수축제외시	233.217	315.000	0.K!!!	1.35

6. 받침용량 검토

구분		고정하중	활하중		지점침하		거더 평균		받침용량
			MAX	MIN	MAX	MIN	MAX	MIN	
P3	SH1	1537.725	595.955	-63.016	23.172	-23.174	2261.882	1488.553	3500
	SH2	1610.910	732.840	-62.183	23.162	-23.156			3500
P4	SH1	4645.840	361.203	-91.632	72.053	-72.054	5387.209	4575.033	8000
	SH2	4836.857	786.441	-96.924	72.023	-72.022			8500
P5	SH1	3783.596	772.652	-121.153	97.721	-97.721	4495.893	3482.414	6500
	SH2	3612.839	627.214	-114.970	97.763	-97.763			7000
P6	SH1	4836.857	786.441	-96.924	72.023	-72.024	5522.209	4575.031	8000
	SH2	4645.840	631.203	-91.632	72.053	-72.056			8500
A2	SH1	1610.910	732.840	-62.183	23.162	-23.160	2261.882	1488.552	3500
	SH2	1537.725	595.955	-63.016	23.172	-23.172			3500

7. 현장이음부 검토

7.1 현장이음의 설계

1) SPLICE - 2 [G2]

(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				
12,873.07	3,485.38	209.400	61.230	353.968	74.31	-69.00	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)

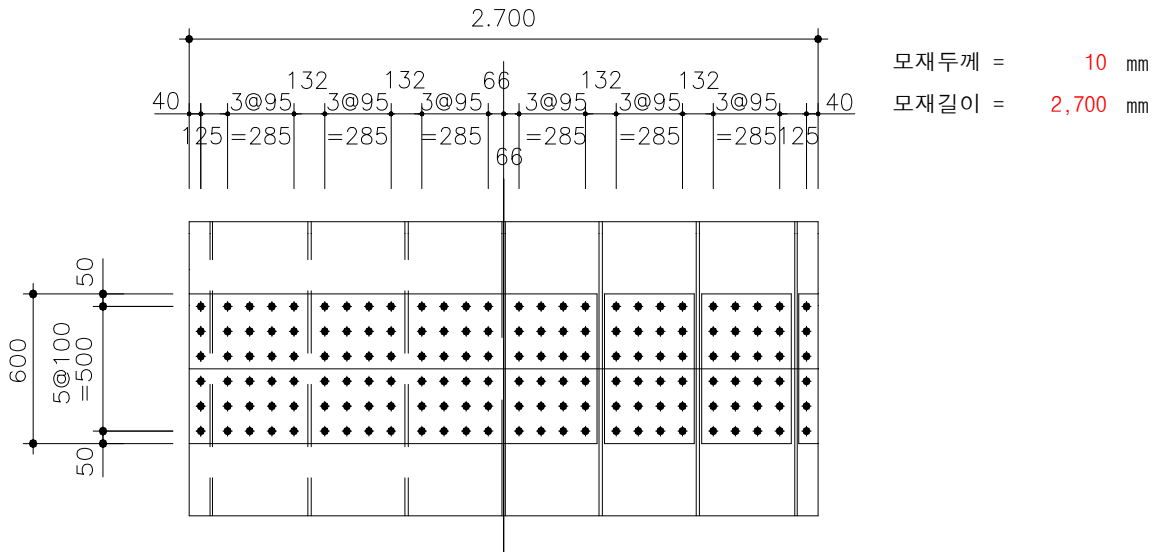
(1) 압축부 플랜지의 이음 : (상부 플랜지)

(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)

$$f_s = 74.311 \text{ MPa}$$

$$f_{s(min)} = 0.75 \times 190.0 = 142.5 \text{ MPa} \quad \therefore \text{이음부의 설계응력 (} f_u \text{) } f_s' = 142.5 \text{ MPa 적용}$$



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

$$\begin{aligned}
 & Q_s, Q_v : \text{합성전 및 합성후의 부재 총단면의 중립축에 대한 전단력을 계산하는 접합선} \\
 & \quad \text{외측의 단면1차 모멘트} \\
 & Q_s = 2,700.0 \times 10.0 \times (1,428.7 - 5.0) = 3.844\text{E}+07 \text{ mm}^3 \\
 & Q_v = 2,700.0 \times 10.0 \times (694.8 - 5.0) = 1.862\text{E}+07 \text{ mm}^3 \\
 & I_s = 2.458\text{E}+11 \text{ mm}^4 \quad (\text{합성전 부재 총단면의 중립축에 대한 단면2차 모멘트}) \\
 & I_v = 4.566\text{E}+11 \text{ mm}^4 \quad (\text{합성후 부재 총단면의 중립축에 대한 단면2차 모멘트}) \\
 & p = \text{플랜지 전폭} / \text{횡방향 BOLT수} = 2,700.0 / 26\text{ea} = 103.8 \text{ mm} \quad (\text{볼트의 피치}) \\
 & n = 3\text{ea} \quad (\text{접합선에 직각방향의 볼트의 수})
 \end{aligned}$$

$$\begin{aligned}
 \rho_h &= (V_s \cdot Q_s / I_s + V_v \cdot Q_v / I_v) \times p / n \\
 &= (209.4 \times 38,439,387.0 / 245,760,781,029.0 + 61.2 \\
 & \quad \times 18,624,600.0 / 456,577,245,526.0) \times (103.8 / 3.0) = 1,220.2 \text{ N/ea}
 \end{aligned}$$

- 축방향력, 휨모멘트 및 전단력이 함께 작용하는 판을 연결할 경우의 BOLT 식

$$\rho = \sqrt{(\rho_p^2 + \rho_h^2)} = \sqrt{2.433\text{E}+09 + 1.489\text{E}+06} = 49,342.0 \text{ N/ea} \leq \rho_{sa} \dots 0.K !!$$

(2) 인장부 플랜지의 이음 : (하부 플랜지)

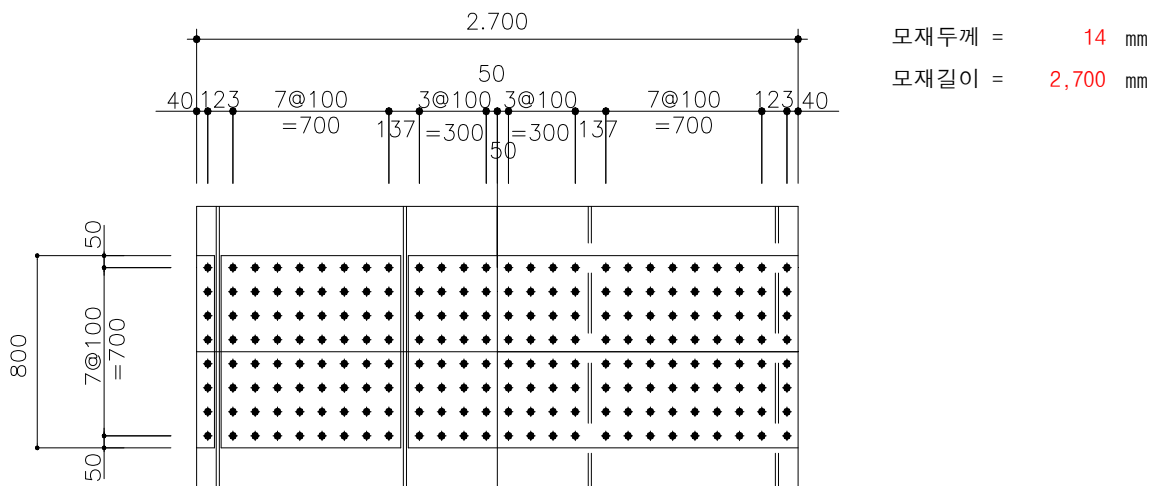
(도.설.해 3.5.3.6)

- 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)

$$f_s = 69.002 \text{ MPa}$$

$$f_s' = 0.75 \times 190.0 = 142.5 \text{ MPa} \quad \therefore \text{이음부의 설계응력} (f_t) = 142.5 \text{ MPa 적용}$$



① 필요 BOLT수의 결정

$$n_{req} = A_s \times f_s' / \rho_{sa} = 37,800.0 \times 142.5 / 96,000.0 = 57\text{ea} \Rightarrow n_t = 104\text{ea} \dots 0.K !!$$

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}

$$1 \text{ PL} - 2,700 \times 14.0 \times 800 = 37,800.0$$

$$4 \text{ PL} - 800 \times 14.0 \times 800 = 44,800.0$$

$$2 \text{ PL} - 80 \times 14.0 \times 800 = 2,240.0$$

$$\Sigma = 84,840.0 \text{ mm}^2$$

- 이음판의 순단면적 (인장부의 순단면적은 BOLT 지름 공제) (도.설.해 3.5.3.7)

$$A_n = 84,840.0 - 25.0 \times 14.0 \times 26.0 \text{열} \times 4ea = 48,440.0 \text{ mm}^2 \geq A_{req} \dots 0.K !!$$

- 이음판의 응력

$$f_s = A_s \times f_s' / A_n = 37,800.0 \times 142.5 / 48,440.0 = 111.2 \text{ MPa} \leq f_{sa} \dots 0.K !!$$

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

$$Q_s = 2,700.0 \times 14.0 \times (1,295.3 - 7.0) = 4.870E+07 \text{ mm}^3$$

$$Q_v = 2,700.0 \times 14.0 \times (2,029.2 - 7.0) = 7.644E+07 \text{ mm}^3$$

$$I_s = 2.458E+11 \text{ mm}^4 \text{ (합성전 부재 총단면의 중립축에 대한 단면2차 모멘트)}$$

$$I_v = 4.566E+11 \text{ mm}^4 \text{ (합성후 부재 총단면의 중립축에 대한 단면2차 모멘트)}$$

$$p = \text{플랜지전폭/횡방향1열BOLT수} = 2,700.0 / 26ea = 103.8 \text{ mm (볼트의 피치)}$$

$$n = 4ea \text{ (접합선에 직각방향의 볼트의 수)}$$

$$\rho_h = (V_s \cdot Q_s / I_s + V_v \cdot Q_v / I_v) \times p / n$$

$$= (209.4 \times 48,698,458.2 / 245,760,781,029.0 + 61.2$$

$$\times 76,439,160.0 / 456,577,245,526.0) \times (103.8 / 4.0) = 1,343.4 \text{ N/ea}$$

- 축방향력, 휨모멘트 및 전단력이 함께 작용하는 판을 연결할 경우의 BOLT 식

$$\rho = \sqrt{(\rho_p^2 + \rho_h^2)} = \sqrt{2.683E+09 + 1.805E+06} = 51,810.7 \text{ N/ea} \leq \rho_{sa} \dots 0.K !!$$

④ 모재의 응력검토

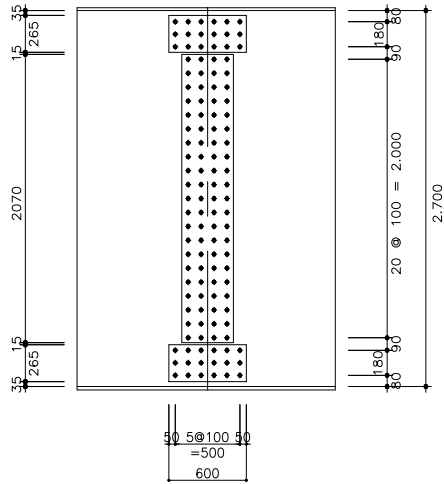
$$A_{sn} = 14.0 \times (2,700.0 - 25.0 \times 26.0) = 28,700.0 \text{ mm}^2$$

$$f_l = A_s \times f_s' / A_{sn} = 37,800.0 \times 142.5 / 28,700.0 = 187.7 \text{ MPa} \leq f_{sa} \dots 0.K !!$$

(3) WEB 연결부의 계산 : (좌측 WEB)

① BOLT의 응력계산

- 휨에 의한 BOLT의 응력



Box 평균 높이 = 2,700 mm

Box 계산 높이 = 2,700 mm

WEB 두께 = 10 mm

중립축에서 연단까지 거리 h_o = 1,350 mm

$$f_1 = f_u = 142.50 \text{ MPa}$$

$$f_2 = f_1 \cdot (h_o - 125) / h_o = 129.31 \text{ MPa}$$

$$f_3 = f_1 \cdot (h_o - 215) / h_o = 119.81 \text{ MPa}$$

$$f_4 = f_1 \cdot (h_o - 305) / h_o = 110.31 \text{ MPa}$$

$$f_5 = f_1 \cdot (h_o - 400) / h_o = 100.28 \text{ MPa}$$

$$f_6 = f_1 \cdot (h_o - 500) / h_o = 89.72 \text{ MPa}$$

$$\text{제1열 } \rho_p = (142.500 + 129.306) / 2 \times 125.0 \times 10.0 / 3ea = 56,626.2 \text{ N/ea} \leq \rho_{sa} \dots\dots 0.K !!$$

$$\text{제2열 } \rho_p = (129.306 + 119.806) / 2 \times 90.0 \times 10.0 / 3ea = 37,366.7 \text{ N/ea} \leq \rho_{sa} \dots\dots 0.K !!$$

$$\text{제3열 } \rho_p = (119.806 + 110.306) / 2 \times 90.0 \times 10.0 / 3ea = 34,516.7 \text{ N/ea} \leq \rho_{sa} \dots\dots 0.K !!$$

$$\text{제4열 } \rho_p = (110.306 + 100.278) / 2 \times 95.0 \times 10.0 / 2ea = 50,013.5 \text{ N/ea} \leq \rho_{sa} \dots\dots 0.K !!$$

$$\text{제5열 } \rho_p = (100.278 + 89.722) / 2 \times 100.0 \times 10.0 / 2ea = 47,500.0 \text{ N/ea} \leq \rho_{sa} \dots\dots 0.K !!$$

$$\sum y_i^2 = 3\text{열} \times 4193400 \times 2 + 2\text{열} \times 3850000 \times 2 = 40,560,400 \text{ mm}^2$$

$$M_w = (f_s \times t_w \times h_w^2) / 6 = (142.5 \times 10 \times 2700^2) / 6 = 1,731,375,000 \text{ Nmm} = 1,731,375 \text{ kNmm}$$

$$\rho_p = (M_w / \sum y_i^2) \times y_n = (1731375 / 40560400) \times 1350 = 57.627 \text{ kN} < 96.000 \text{ kN } 0.K!!!$$

- 전단력에 의한 BOLT의 응력 (도.설.해 3.8.2.3)

∴ 전단응력 $\sigma = V / A_w + M_t / (2 \cdot F \cdot t_w)$ [비틀림 모멘트 고려시]

- 한쪽 복부판이 부담하는 전단력 : $(V_s + V_v) / 2 = (209.4 + 61.2) / 2 = 135,315.0 \text{ N}$
- 비틀림 모멘트에 의한 복부의 전단력 : $M_t / (2 \cdot b) = 354.0 / (2 \times 400) = 442,460.0 \text{ N}$

따라서, 전단력에 의한 볼트의 응력은

$$\rho_s = (135,315.0 + 442,460.0) / 60ea = 9,629.6 \text{ N/ea} \leq \rho_{sa} \dots 0.K !!$$

- 합성 응력의 검토

$$\rho = \sqrt{(\rho_p^2 + \rho_s^2)} = \sqrt{(56,626.2^2 + 9,629.6^2)} = 57,439.1 \text{ N/ea} \leq \rho_{sa} \dots 0.K !!$$

② 이음판의 응력계산

- 복부판의 단면2차 모멘트

- 합성전 단면2차 모멘트

$$I_{sw}^1 = (10.0 \times 2,700.0^3) / 12 + 10.0 \times 2,700.0 \times (1,350.0 - 1,295.3)^2 = 1.648E+10 \text{ mm}^4$$

- 합성후 단면2차 모멘트

$$I_{vw}^1 = (10.0 \times 2,700.0^3) / 12 + 10.0 \times 2,700.0 \times (2,029.2 - 1,350.0)^2 = 2.886E+10 \text{ mm}^4$$

- 복부판에 작용하는 모멘트

- 복부에 작용하는 합성전 고정하중에 의한 모멘트

$$M_{sw} = M_s \times I_{sw}^1 / I_s = 12,873.1 \times 16,483,230,317.5 \times 245,760,781,029.0 = 863.4 \text{ kN} \cdot \text{m}$$

- 복부에 작용하는 합성후 하중에 의한 모멘트

$$M_{vw} = M_v \times I_{vw}^1 / I_v = 3,485.4 \times 28,857,941,280.0 \times 456,577,245,526.0 = 220.3 \text{ kN} \cdot \text{m}$$

- 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 - 265.0 × 10.0	10,600.0	1,182.5	1.253E+07	1.482E+10	6.203E+07
2 - 2,070.0 × 10.0	41,400.0	-	-	-	1.478E+10
합계	52,000.0	1,182.5	1.253E+07	1.482E+10	1.484E+10

$$I = I_o + AY^2 = 14,844,937,083.3 + 14,822,046,250.0 = 2.967E+10 \text{ mm}^4$$

- 합성전 단면의 중립축에 대한 이음판의 총단면2차모멘트

$$I_{sw} = 29,666,983,333.3 + 52,000.0 \times (1,350.0 - 1,295.3)^2 = 2.982E+10 \text{ mm}^4$$

- 합성후 단면의 중립축에 대한 이음판의 총단면2차모멘트

$$I_{vw} = 29,666,983,333.3 + 52,000.0 \times (2,029.2 - 1,350.0)^2 = 5.366E+10 \text{ mm}^4$$

- 이음판의 응력 검토

- 합성전 단면의 중립축에서 이음판 상·하연까지의 거리

$$y_{su} = 1,428.7 \text{ mm} \quad y_{sl} = 1,295.3 \text{ mm}$$

- 합성후 단면의 중립축에서 이음판 상·하연까지의 거리

$$y_{su,v} = 694.8 \text{ mm} \quad y_{sl,v} = 2,029.2 \text{ mm}$$

- 이음판의 상연 응력 검토

$$\begin{aligned} f_u &= (M_{sw} \cdot y_{su}) / I_{sw} + (M_{vw} \cdot y_{su,v}) / I_{vw} \\ &= (863.4 \times 1,428.7) / 29,822,463,944.9 + (220.3 \times 694.8) / 53,655,240,613.3 \\ &= 41.362 + 2.853 = 44.215 \text{ MPa} \leq f_{sa} = 190.000 \text{ MPa} \dots 0.K !! \end{aligned}$$

- 이음판의 하연 응력 검토

$$\begin{aligned} f_l &= (M_{sw} \cdot y_{sl}) / I_{sw} + (M_{vw} \cdot y_{sl,v}) / I_{vw} \\ &= (863.4 \times 1,295.3) / 29,822,463,944.9 + (220.3 \times 2,029.2) / 53,655,240,613.3 \\ &= 37.501 + 8.331 = 45.833 \text{ MPa} \leq f_{sa} = 190.000 \text{ MPa} \dots 0.K !! \end{aligned}$$

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)

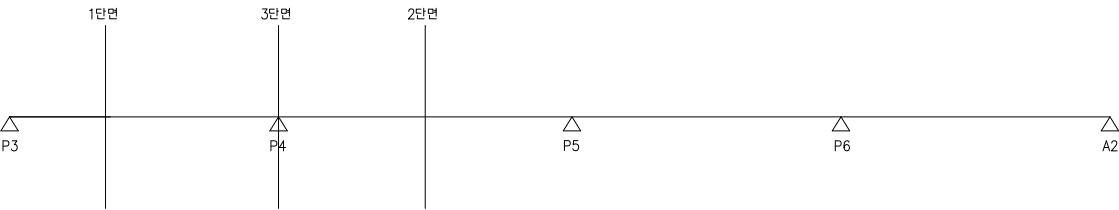
응 력 범 주	다재하 경로구조				단재하 경로구조			
	10 만회	50 만회	200 만회	200 만회이상	10 만회	50 만회	200 만회	200 만회이상
A	442	260	168	168	351	203	168	168
B	344	203	126	112	274	161	112	112
B'	274	161	101	84	218	126	77	77
C	250	147	91	70	196	112	70	63
				84*			84*	77*
D	196	112	70	49	154	91	56	35
E	154	91	56	31	119	70	42	16
E'	112	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

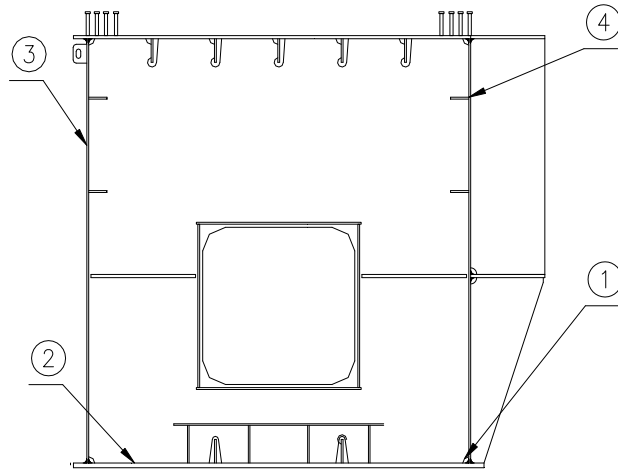
활하중에 의한 모멘트의 변동범위가 큰 단면에서 인장응력 및 교번응력이 발생하는 상세부에 대하여 피로검토를 수행 한다.

- 피로조사 단면위치



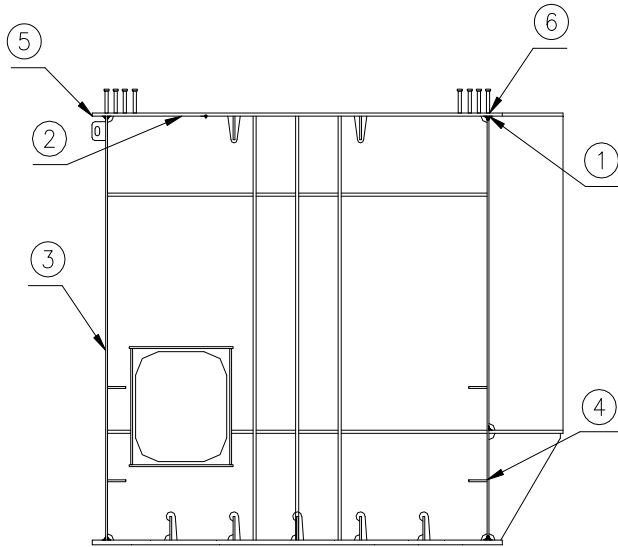
본 교량은 **고속도로** 에 속하는 **다재하경로** 구조로서 트럭하중 2백만회 와 차선하중 50만회 에 대하여 검토 하는 것으로 한다.

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	8348.773	9904.864	4.566E+11	2039	37.288	44.238	B	126	203	O.K.
②				2039	37.288	44.238	C	91	147	O.K.
③				1139	20.827	24.709	E	56	91	O.K.
④				119	2.174	2.579	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	3912.007	3178.086	3.800E+11	2125	21.873	17.770	B	126	203	O.K.
②				2125	21.873	17.770	C	91	147	O.K.
③				1270	13.070	10.618	E	56	91	O.K.
④				204	2.102	1.708	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	5494.009	10891.191	3.726E+11	1399	20.624	40.885	B	126	203	O.K.
②				1399	20.624	40.885	C	91	147	O.K.
③				620	9.142	18.123	E	56	91	O.K.
④				902	13.299	26.363	E	56	91	O.K.
⑤				1415	20.860	41.352	E	56	91	O.K.
⑥				1431	21.096	41.820	C	91	147	O.K.

· 전단에 대한 피로검토 - 플랜지와 복부판의 필릿용접부에 대한 전단피로검토

이 부위의 피로상세범주는 "F" 이며, 검토 단면은 전단력이 가장 큰 절점 180 을 설정 하였음

$$\Delta \sigma = \frac{\Delta S \cdot Q}{I_v \cdot \Sigma a}$$

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

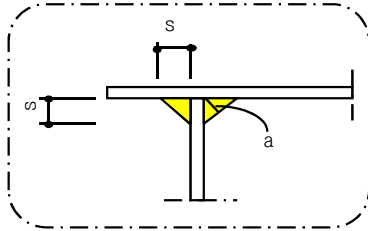
단면 1차 모멘트 ($\text{mm}^3 = A(\text{mm}^2) \cdot y(\text{mm})$)

$y = Y_{vsu}(l) - t_u(l)/2$

I_v : 합성후 단면의 단면2차 모멘트

Σa : 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)	Σa (mm)	$\Delta \sigma$ (MPa)	σ_{sr} (MPa)	비고
DB하중	1296.178	30	2500	75000	1084	8.119E+07	#####	8	22.6	12.5	63	OK
DL하중	2038.253									19.6	84	OK

- 하부 플랜지와 복부판

구분	ΔS (kN)	t_l (mm)	B (mm)	A (mm^2)	Y_{vsu} (mm)	Q (mm^3)	I_v (mm^4)	s (mm)	Σa (mm)	$\Delta \sigma$ (MPa)	σ_{sr} (MPa)	비고
DB하중	1296.178	32	2500	80000	1382	1.104E+08	#####	8	22.6	17.0	63	OK
DL하중	2038.253									26.7	84	OK