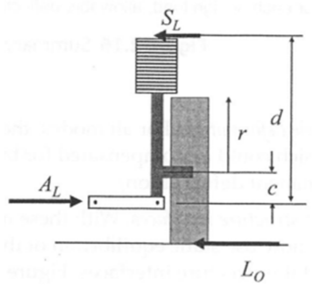
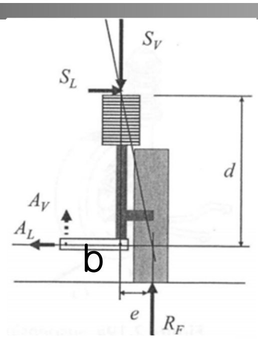
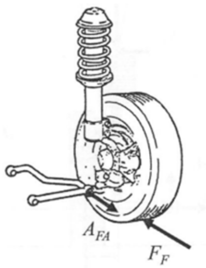
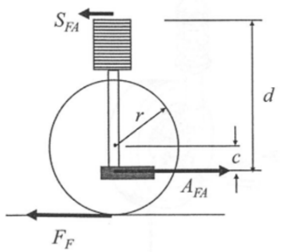
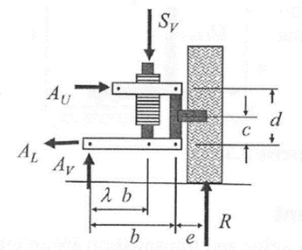
2.5 Struct vs.SLA



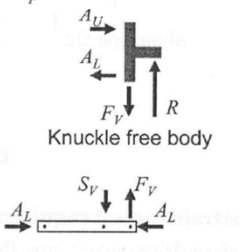




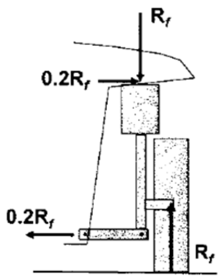


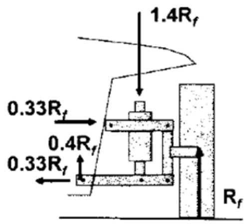


Suspension free body: front view



Lower arm free body





Struct

For the maximum lateral tire patch load during rollover mode

$$M_{@A_L}: S_L d - (r-c)L_0 = 0$$

$$\rightarrow S_L = \left(\frac{r-c}{d}\right)L_0$$

$$M_{@S_L}: A_L d - (d+(r-c))L_0 = 0$$

$$\rightarrow A_L = \left(\frac{r-c}{d}+1\right)L_0$$

For the maximum fore-aft tire patch load during braking mode

$$M_{@A_{FA}}: F_F(r-c) - dS_{FA} = 0$$

$$\rightarrow S_{FA} = \left(\frac{r-c}{d}\right)F_F$$

$$M_{@S_{FA}}: A_{FA}d - (d+(r-c))F_F = 0$$

$$\rightarrow A_{FA} = \left(\frac{r-c}{d}+1\right)F_F$$

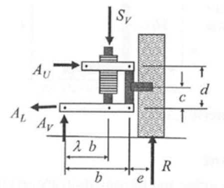
For the maximum vertical tire patch load during bump mode

$$F_x: A_L - S_L = 0 \rightarrow S_L = A_L$$

$$F_y: R_F - S_V - A_V = 0 \rightarrow S_V = R_F - A_V$$

$$if\ A_V = 0\ (or\ S_V \gg A_V),\ S_V = R_F$$

SLA



Suspension free body: front view

1) S_V

$$F_x: A_U - A_L = 0 \rightarrow A_U = A_L$$

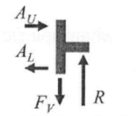
$$F_y: S_V - A_V - R = 0 \rightarrow S_V = R + A_V$$

$$M_{@lowerarm,F_V}: bA_V - (b-\lambda b)S_V = 0 \rightarrow A_V = (1-\lambda)S_V$$

$$\rightarrow S_V - R = (1-\lambda)S_V \rightarrow S_V = \frac{1}{\lambda}R$$

2) A_U

$$M_{@knuckle,F_V}: eR - dA_U = 0 \rightarrow A_U = \frac{e}{d}R$$



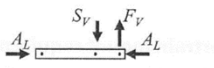
Knuckle free body

3) A_L, A_V

$$A_L = A_U = \frac{e}{d}R$$

$$A_V = A_V = (1-\lambda)S_V = (1-\lambda)\frac{1}{\lambda}R$$

$$= (\frac{1}{\lambda}-1)R$$



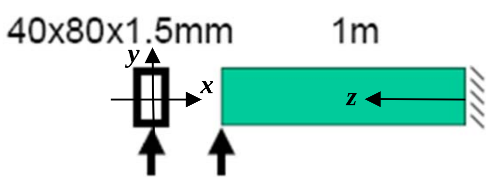
Lower arm free body

$\lambda = 0.7$ 인 경우

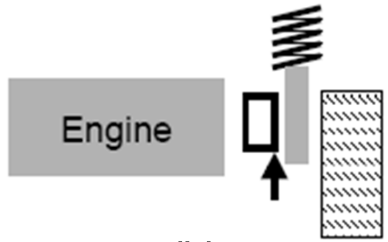
$$\text{Strut}: S_V = R,\ \ \text{SLA}: \frac{1}{\lambda}R = \frac{1}{0.7}R \approx 1.43R$$

SLA가 Struct보다 Sv (spring-shock maximum load)가 1.43배 커서 우수함

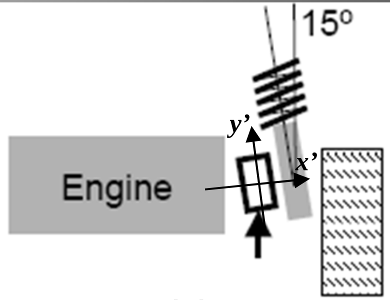
3.2 Motor Compartment Rail (1)



(a)



(b)



(c)

(a) load at the centroid

$$I_x = \frac{40(80)^3}{12} - \frac{37(77)^3}{12} = 2.9902 \times 10^5 \, mm^4$$

$$\sigma_z = -\frac{My}{I_x} = -\frac{(2000N)(1000mm)(40mm)}{2.9902 \times 10^5 \, mm^4} = -267.5 N/mm^2$$

$$\delta = \frac{Fl^3}{3EI} = \frac{(2000N)(1000mm)^3}{3\left(207 \times 10^3 N/mm^2\right)\left(2.9902 \times 10^5 mm^4\right)} = 10.4mm$$

(b) load at the corner $\rightarrow$ load at the centroid + torsion(clockwise)

$$I_x = \frac{40(80)^3}{12} - \frac{37(77)^3}{12} = 2.9902 \times 10^5 \, mm^4$$

$$\sigma_z = -\frac{My}{I_x} = -\frac{(2000N \times 1000mm)(40mm)}{2.9902 \times 10^5 \, mm^4} = -267.5 N/mm^2$$

$$\delta_y = \frac{Fl^3}{3EI} = \frac{(2000N)(1000mm)^3}{3\left(207 \times 10^3 N/mm^2\right)\left(2.9902 \times 10^5 mm^4\right)} = 10.8mm$$

$$\tau_{xy} = \frac{T}{2At} = \frac{(2000N \times 20mm)}{2\left(38.5 \times 78.5mm^2\right)(1.5mm)} = 4.4 N/mm^2$$

$$\theta = \frac{Tl}{GJ_{eff}} = \frac{Tl}{G\frac{4A^2t}{S}} = \frac{(2000N \times 20mm)(1000mm)2(38.5 + 78.5mm)}{4\left(80 \times 10^3 N/mm^2\right)\left(38.5 \times 78.5mm^2\right)^2(1.5mm)} = 0.002rad$$

$$\delta_{total} = \delta_y + \sqrt{20^2 + 40^2}\,\theta$$

3.2 Motor Compartment Rail (2)

(c) section rotated 15°

$$I_{x'} = \frac{40(80)^3}{12} - \frac{37(77)^3}{12} = 2.9902 \times 10^5 mm^4$$

$$I_{y'} = \frac{80(40)^3}{12} - \frac{77(37)^3}{12} = 1.0164 \times 10^5 mm^4$$

$$F_{y'} = F\cos 15° = 1931.9$$

$$F_{x'} = F\sin 15° = 517.6$$

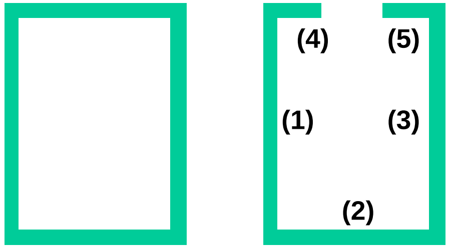
$$\sigma_z = -\frac{M_{y'}y'}{I_{x'}} - \frac{M_{x'}x'}{I_{y'}} = -\frac{(1931.9N \times 1000mm)(40mm)}{2.9902 \times 10^5 mm^4} - \frac{(517.6N \times 1000mm)(20mm)}{1.0164 \times 10^5 mm^4} = -360.3N/mm^2$$

$$\delta_{y'} = \frac{F_{y'}l^3}{3EI_{y'}} = \frac{(1931.9N)(1000mm)^3}{3\left(207 \times 10^3 N/mm^2\right)\left(2.9902 \times 10^5 mm^4\right)} = 10.4mm$$

$$\delta_{x'} = \frac{F_{x'}l^3}{3EI_{x'}} = \frac{(517.6N)(1000mm)^3}{3\left(207 \times 10^3 N/mm^2\right)\left(1.0164 \times 10^5 mm^4\right)} = 8.2mm$$

$$\delta = \sqrt{\left(\delta_{x'}\right)^2 + \left(\delta_{y'}\right)^2} = 13.2mm$$

3.16 Effective Width



$$\sigma_{cr} = k\frac{E\pi^2}{12(1-\nu^2)}\frac{1}{(b/t)^2} = 4\frac{\pi^2\left(207\times10^3 N/mm^2\right)}{12\left(1-0.3^2\right)\left(100mm/0.86mm\right)^2} = 53.35N/mm^2$$

$$I = \frac{100(150)^3}{12} - \frac{98.28(148.28)^3}{12} = 1.4237\times10^6 mm^4$$

$$\sigma_{cr} = \frac{M_{cr}(75mm)}{I} \rightarrow M_{cr} = 1.0128\times10^6 Nmm$$

$$w = \frac{1}{2}\left(1+\frac{\sigma_{cr}}{\sigma_s}\right)b \rightarrow \begin{cases} \sigma_s = 1.1\sigma_{cr} : w = 95.5mm \\ \sigma_s = 1.5\sigma_{cr} : w = 83.3mm \\ \sigma_s = 2.0\sigma_{cr} : w = 75.0mm \end{cases}$$

b	100	mm
h	150	mm
t	0.86	mm
w	75	mm

(Ix)nom
1.42E+06

part	width	height	x	y	area	x*area	y*area	Ix'	d	Ix
1	0.86	150.00	0.43	75.00	129.00	55.47	9675.00	2.42E+05	3.95	2.44E+05
2	98.28	0.86	50.00	0.43	84.52	4226.04	36.34	5.21E+00	-70.62	4.21E+05
3	0.86	150.00	99.57	75.00	129.00	12844.53	9675.00	2.42E+05	3.95	2.44E+05
4	36.64	0.86	19.18	149.57	31.51	604.37	4713.01	1.94E+00	78.52	1.94E+05
5	36.64	0.86	80.82	149.57	31.51	2546.67	4713.01	1.94E+00	78.52	1.94E+05
sum					405.54	20277.08	28812.37			1.30E+06
centroid			50.00	71.05				Ix/(Ix)nom		0.91

(σ)y	207	N/mm^2
y	78.95	mm
My	3.40E+06	Mmm

4.2 Body Bending: Backbone Structure

(a) strength requirement: $\sigma_{allow} = \dfrac{Mc}{I} = \dfrac{\left(\dfrac{F_{\max} L}{4}\right)c}{I} \rightarrow I_{strength} = \dfrac{LcF_{\max}}{4\sigma_{allow}} = \dfrac{(2790mm)(150mm)(6670N)}{4\left(175N/mm^2\right)} = 3.99\times10^6\,mm^4$

$$I_{strength} = \frac{h^2 t(3w+h)}{6} \rightarrow t = \frac{6I_{strength}}{h^2(3w+h)} = \frac{6\left(3.99\times10^6\,mm^4\right)}{(300mm)^2(3\times200mm+300mm)} = 0.295mm$$

(b) stiffness requirement: $\delta = \dfrac{F_{\max}L^3}{48EI} \rightarrow I_{stiffness} = \dfrac{F_{\max}L^3}{48E\delta} = \dfrac{(6670N)(2790mm)^3}{48\left(207,000N/mm^2\right)(1mm)} = 1.46\times10^7\,mm^4$

$$I_{stiffness} = \frac{h^2 t(3w+h)}{6} \rightarrow t = \frac{6I_{strength}}{h^2(3w+h)} = \frac{6\left(1.46\times10^7\,mm^4\right)}{(300mm)^2(3\times200mm+300mm)} = 1.08mm$$

(f) $I_{strength} = I_{stiffness} \rightarrow \dfrac{LcF_{\max}}{4\sigma_{allow}} = \dfrac{F_{\max}L^3}{48E\delta}$

$$\rightarrow L = \sqrt{\frac{12E\delta c}{\sigma_{allow}}} = \sqrt{\frac{12\left(207,000N/mm^2\right)(1mm)(150mm)}{175N/mm^2}} = 1459mm\,(< 2790mm)$$

$\rightarrow$ 2-seat car has balanced strength and stiffness requirements.

5.3 Body Torsion: Backbone Structure

(a) strength: $\tau_{allow} = \dfrac{T}{2At} \rightarrow t = \dfrac{T}{2A\tau_{allow}} = \dfrac{6,780,000\,Nmm}{2\left(200mm \times 300mm\right)\left(86N/mm^2\right)} = 0.657mm$

(b) stiffness: $\theta = \dfrac{Tl}{GJ_{eff}} \rightarrow k = \dfrac{T}{\theta} = \dfrac{GJ_{eff}}{l} \xrightarrow{J_{eff} = \frac{4A^2}{\oint \frac{dS}{t}} = \frac{4A^2 t}{S}} k = \dfrac{T}{\theta} = \dfrac{G\left(4A^2 t\right)}{lS}$

$$\rightarrow t = \frac{klS}{4A^2 G} = \frac{\left(12,000,000\,\frac{Nmm}{\deg}\,\frac{360\deg}{2\pi rad}\right)\left(2790mm\right)2\left(200mm + 300mm\right)}{4\left(200mm \times 300mm\right)^2\left(83,000N/mm^2\right)} = 1.605mm$$

(c) $t_{strength} < t_{stiffness}$

$\rightarrow$ The stiffness requirement is dominant assuming that the walls are stable and do not undergo plate buckling.

5.13 Torsion of Sedan

$$
\begin{bmatrix}
h_1 & w & 0 & 0 & 0 & 0 & 0 \\
l_S & 0 & -w & 0 & 0 & 0 & 0 \\
l_R & 0 & 0 & -w & 0 & 0 & 0 \\
l_B & 0 & 0 & 0 & -w & 0 & 0 \\
h_2 & 0 & 0 & 0 & 0 & w & 0 \\
l_F & 0 & 0 & 0 & 0 & 0 & -w \\
0 & 0 & 0 & \left(h_0 - h_1\right) & \left[l_F\left(h_0 - h_2\right) + l_2\left(h_2 - h_1\right)\right] / l_B & -l_F & h_1
\end{bmatrix}
\begin{bmatrix} Q_1 \\ Q_2 \\ Q_3 \\ Q_4 \\ Q_5 \\ Q_6 \\ Q_7 \end{bmatrix}
=
\begin{bmatrix} -T \\ 0 \\ 0 \\ 0 \\ -T \\ 0 \\ 0 \end{bmatrix}
\begin{array}{c} \text{dash} \\ \text{windshield} \\ \text{roof} \\ \text{backlight} \\ \text{rear seat panel} \\ \text{floor} \\ \text{side frame} \end{array}
$$

$$
\rightarrow
\begin{bmatrix}
750 & 1500 & 0 & 0 & 0 & 0 & 0 \\
707 & 0 & -1500 & 0 & 0 & 0 & 0 \\
1250 & 0 & 0 & -1500 & 0 & 0 & 0 \\
559 & 0 & 0 & 0 & -1500 & 0 & 0 \\
750 & 0 & 0 & 0 & 0 & 1500 & 0 \\
2000 & 0 & 0 & 0 & 0 & 0 & -1500 \\
0 & 0 & 0 & 500 & 1789 & -2000 & 750
\end{bmatrix}
\begin{bmatrix} Q_1 \\ Q_2 \\ Q_3 \\ Q_4 \\ Q_5 \\ Q_6 \\ Q_7 \end{bmatrix}
=
\begin{bmatrix} -T \\ 0 \\ 0 \\ 0 \\ -T \\ 0 \\ 0 \end{bmatrix}
$$