Department of
Automotive Engineering

Computational Design Lab

Topology Optimization for Front Crossmember

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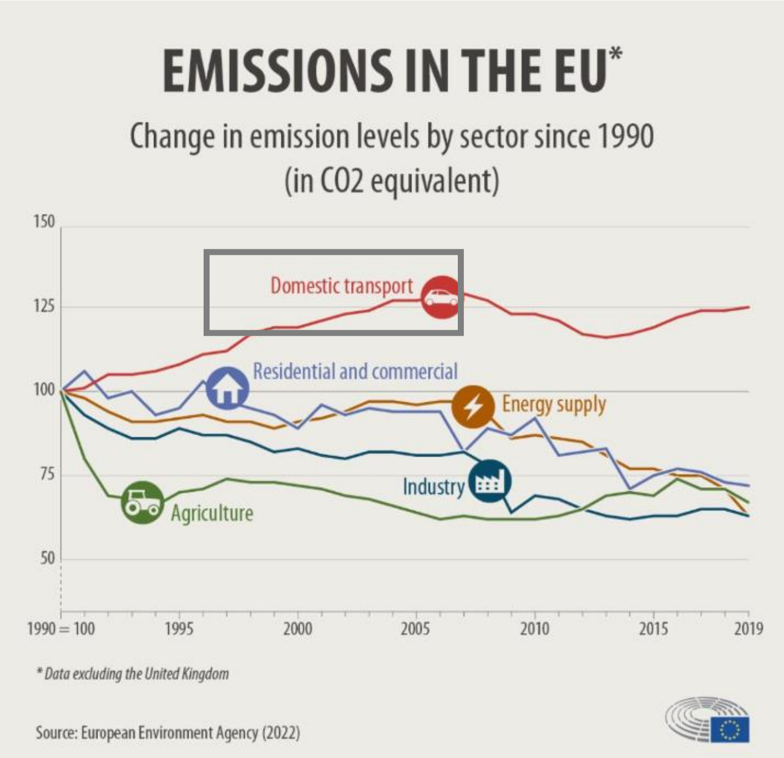
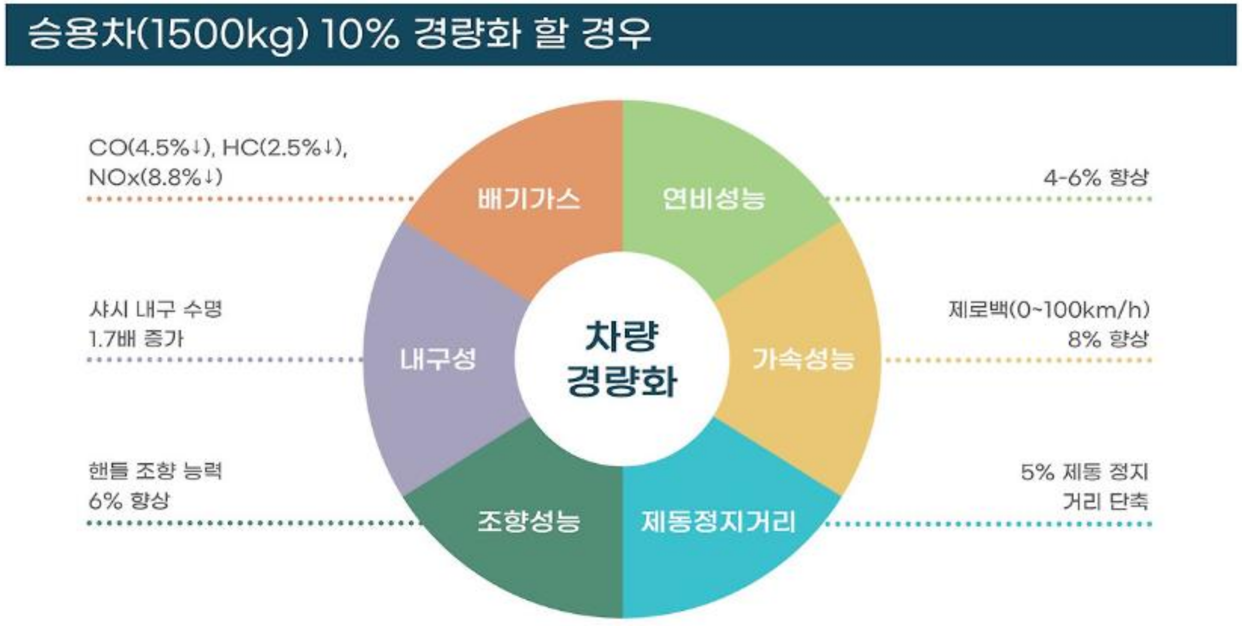
HANYANG UNIVERSITY

Outline

- Motivation
- Modeling
- Topology Optimization
- Future Work

Motivation

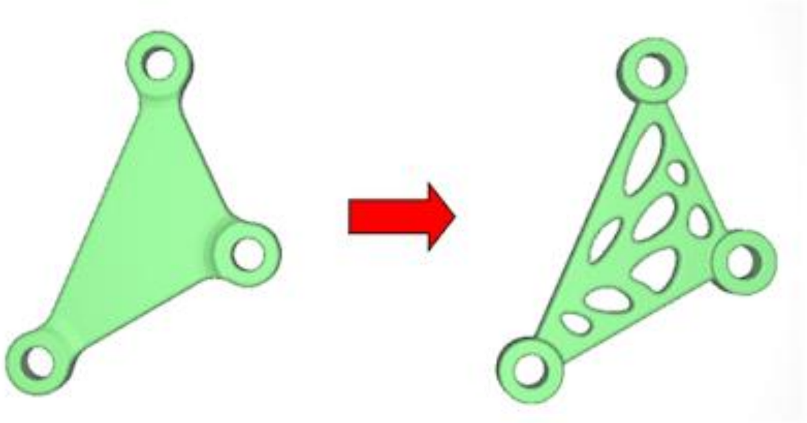




자동차 경량화에 따른 효과.[한국자동차연구원 제공]

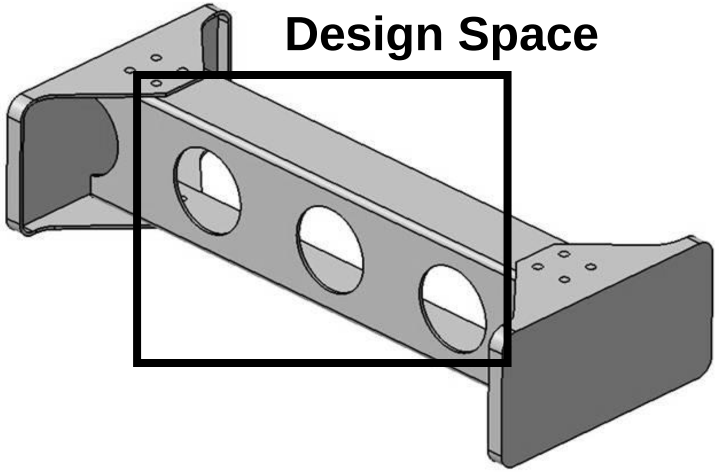
Motivation

Topology Optimization

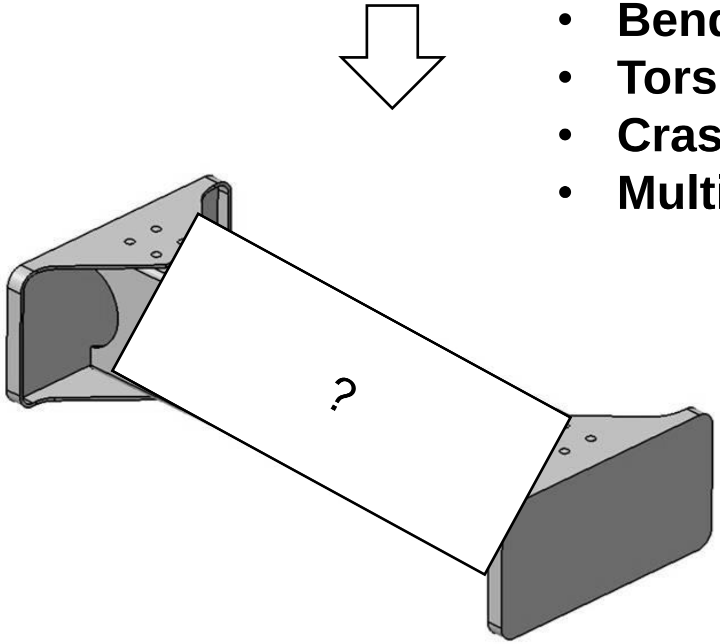


Initial Design Optimal Design

Design Space

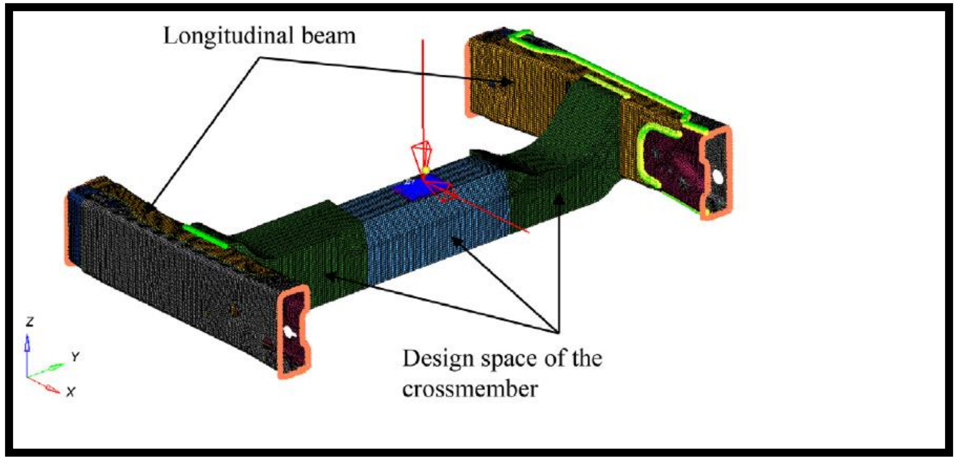


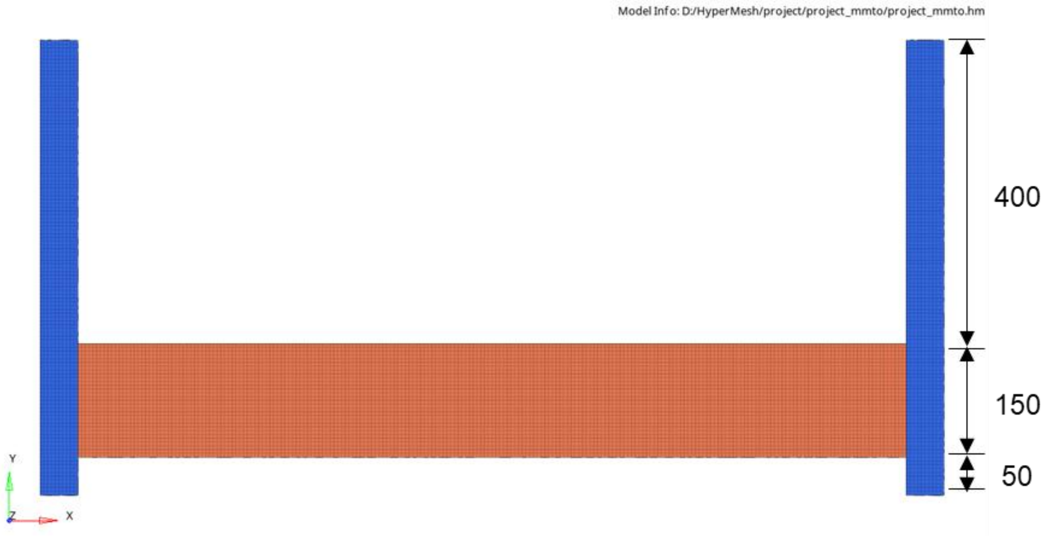
- Bending
- Torsion
- Crashworthiness
- Multiple load cases

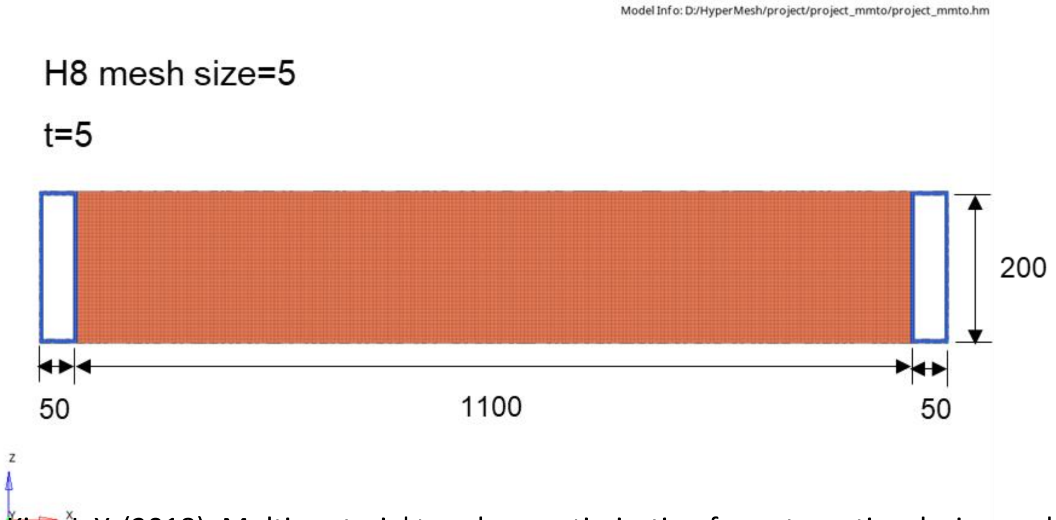


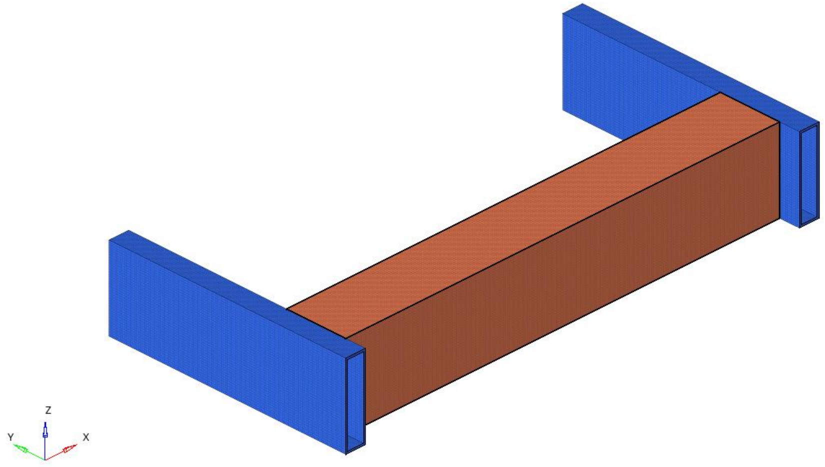
Modeling

- **Reference Model**









Li, C., & Kim, I. Y. (2018). Multi-material topology optimization for automotive design problems. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 232*(12), 1590–1609.

Modeling

그림 1.5

정적 휠 하중의 계산

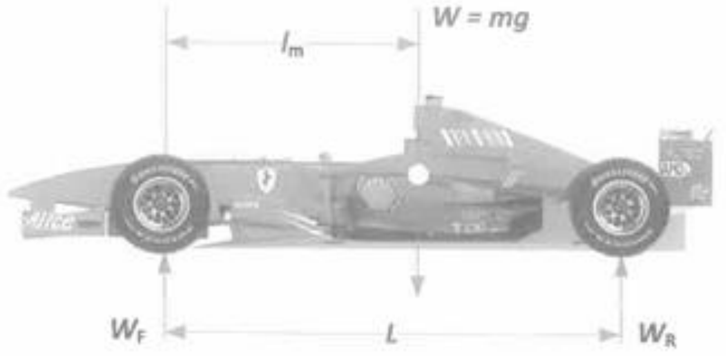


그림 1.5는 질량 중심의 위치와 크기가 확인된 자동차를 보여주고 있다. 이제 정적 휠 하중을 계산할 것이다. 휠베이스와 질량 중심의 수평위치를 알고 있기 때문에 프론트액슬을 중심으로 하는 모멘트를 계산함으로써 리어액슬 하중 W_R 을 다음과 같이 계산할 수 있다.

리어액슬 하중, $W_R = W \times \frac{l_m}{L}$

프론트액슬 하중, $W_F = W - W_R$

예제 1.5

예제 1.3과 1.4 그리고 그림 1.17과 동일한 자동차에 대해서,

(a) 타이어와 노면 사이의 평균 마찰 계수 μ 를 1.5로 가정하고 코너링 포스를 계산하시오.

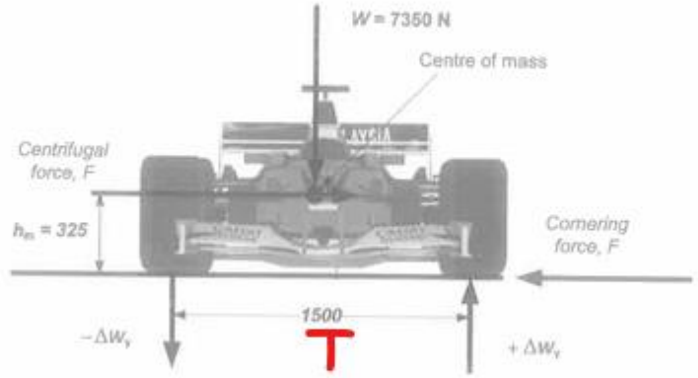
(b) 최대 전체 가로 방향 하중 이동을 계산하시오.

(c) 자동차가 100m 반경의 코너를 주행할 수 있는 속도를 예측하시오.

그림 1.17

코너링 동안 전체 가로 방향

하중 이동 계산



풀이

(a) 식 [1.12]로부터,

최대 코너링 포스, $F = W \times \mu = 7350 \times 1.5 = 11025N$

(b) 식 [1.13]으로부터,

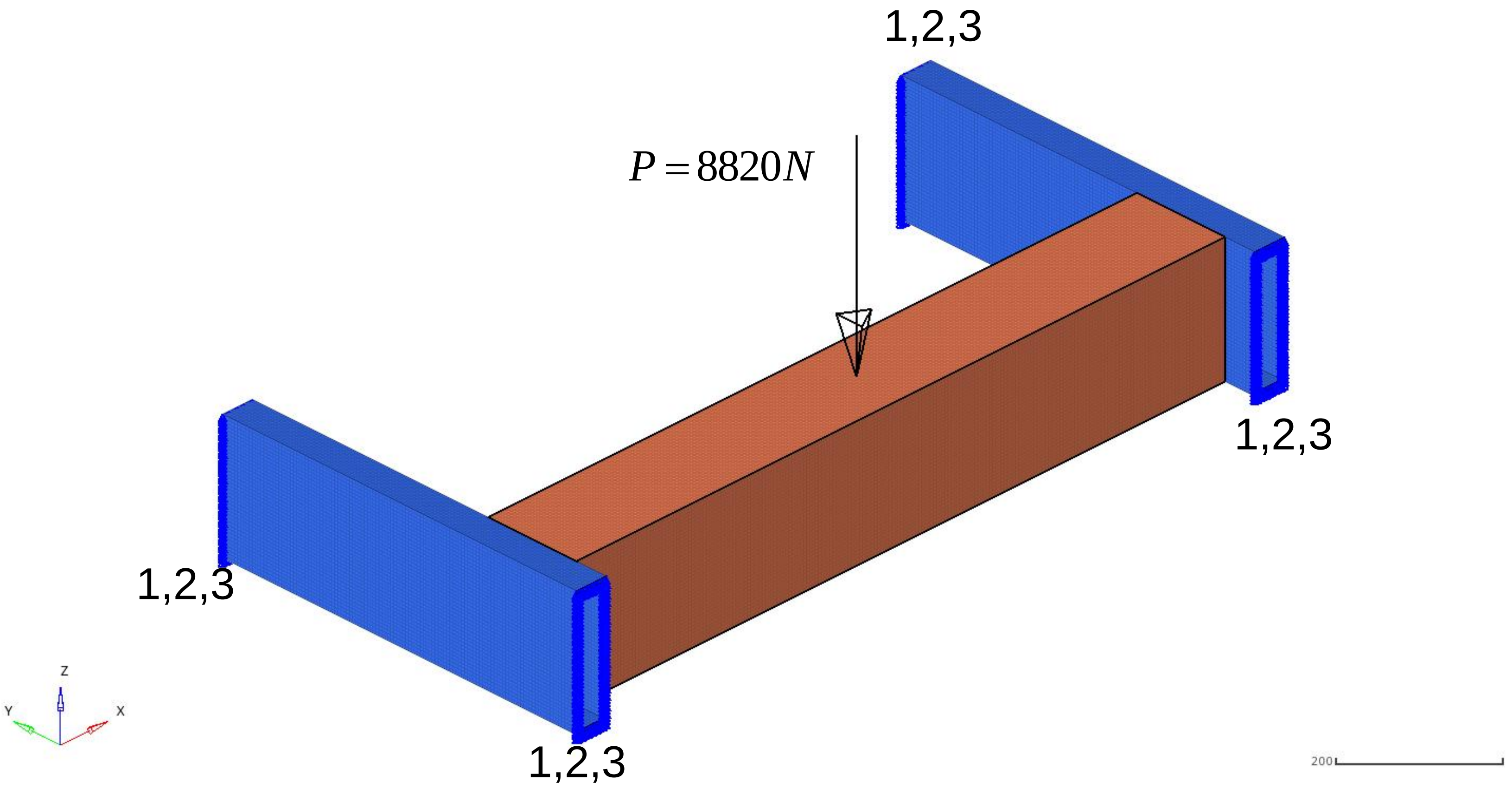
전체 가로 방향 하중 이동, $\Delta W_y = \pm \frac{Fh_m}{T} = \pm \frac{11025 \times 325}{1500} = \pm 2389N$

The information for calculating loads is based on the Genesis G80.

Seward, D. (2019). *레이싱카 디자인* (권태화, 역). 노이하우스. (원저 출판 2014)

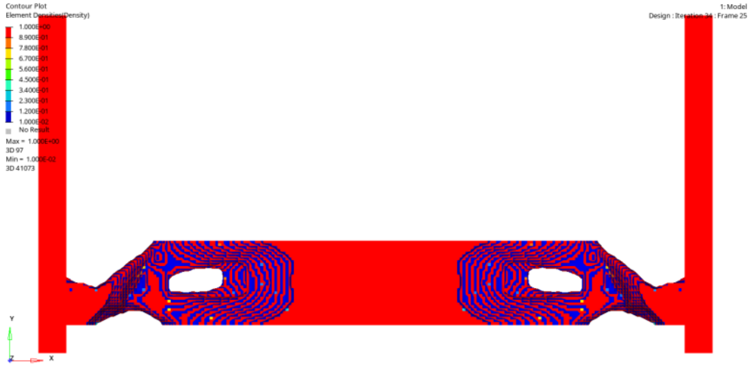
Single Material Topology Optimization - Bending

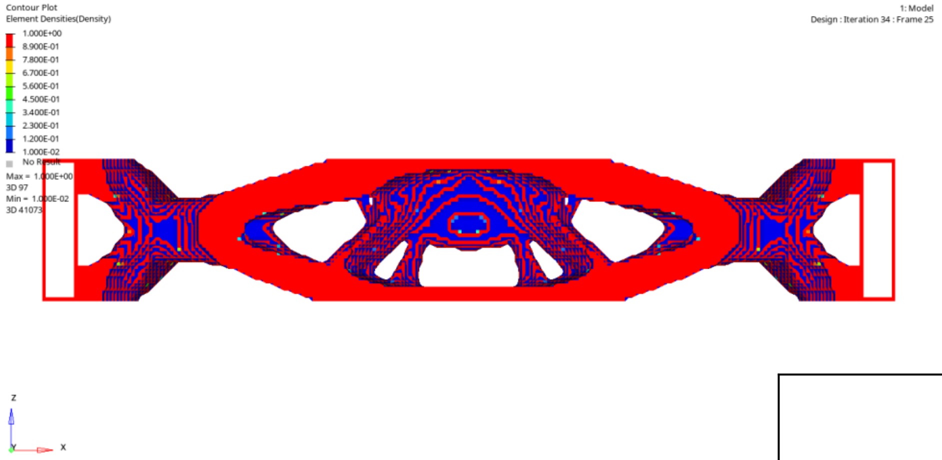
CDL Computational Design Lab

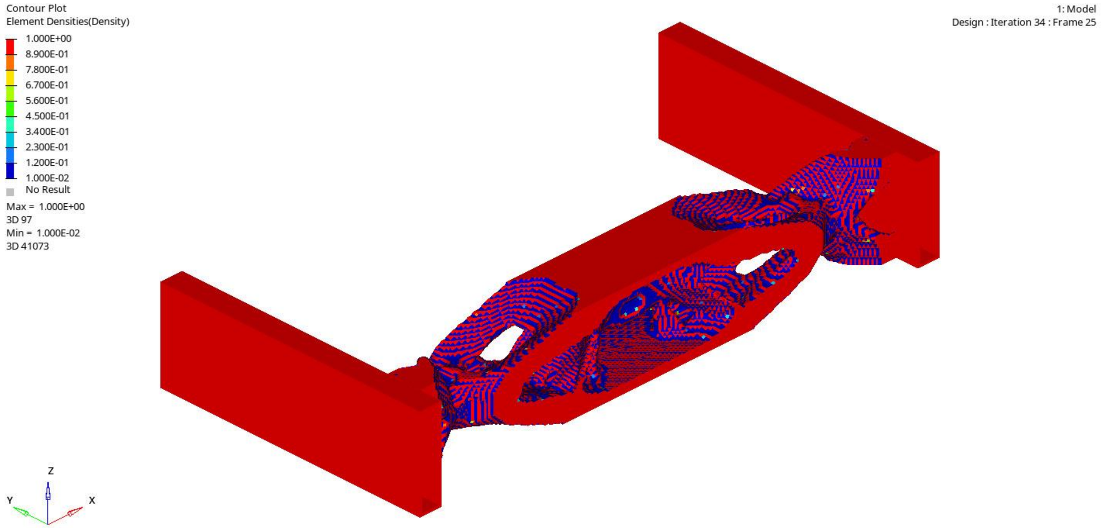


$$\min : C$$
$$s.t : \text{Volume fraction} \leq 0.3$$

SMTO - Bending



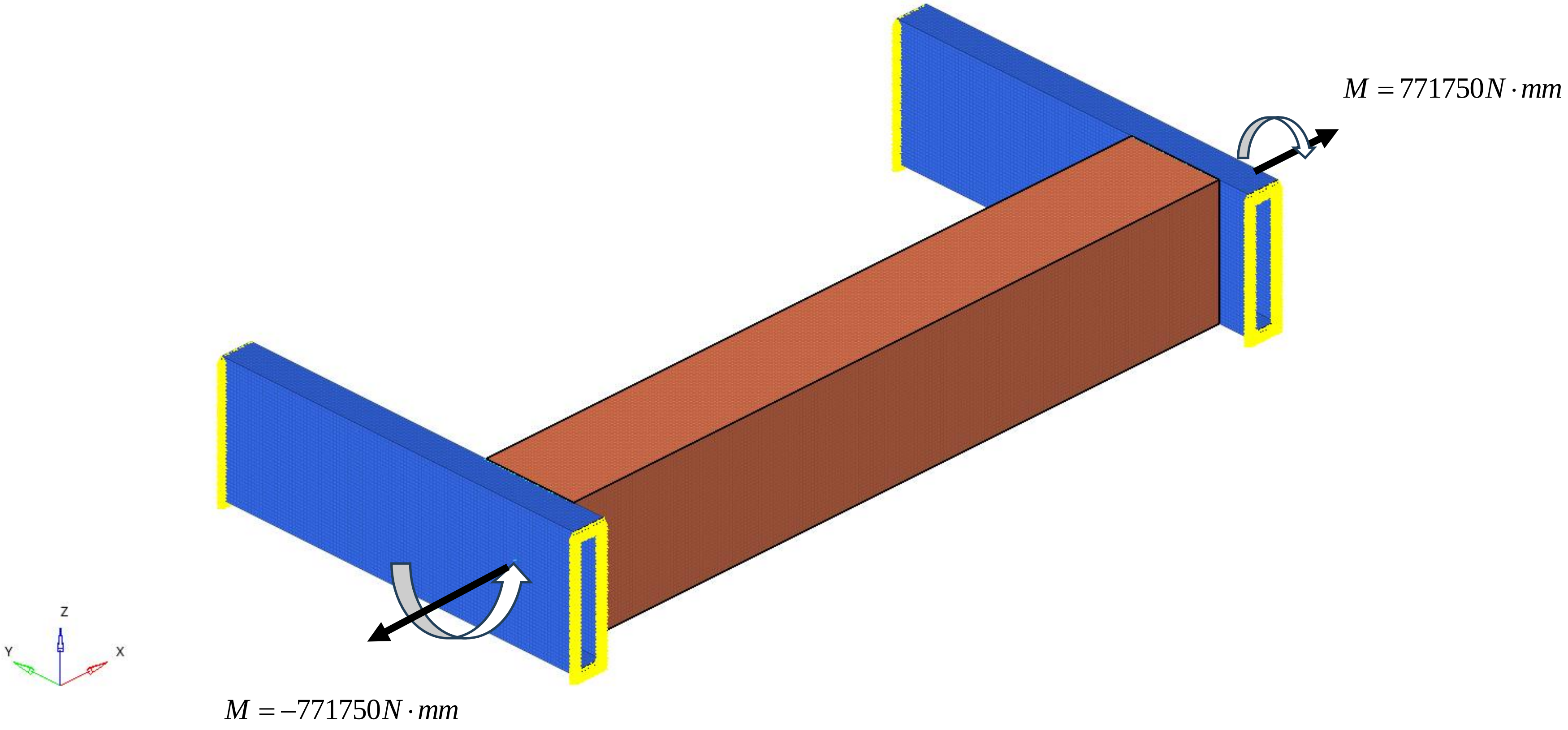




	Compliance [Nmm]	Volume Fraction (Steel)	Mass [kg]
Initial Design	1.11022E+04	0.3	7.772E-02
Optimal Design	2.449E+02	0.3	7.772E-02

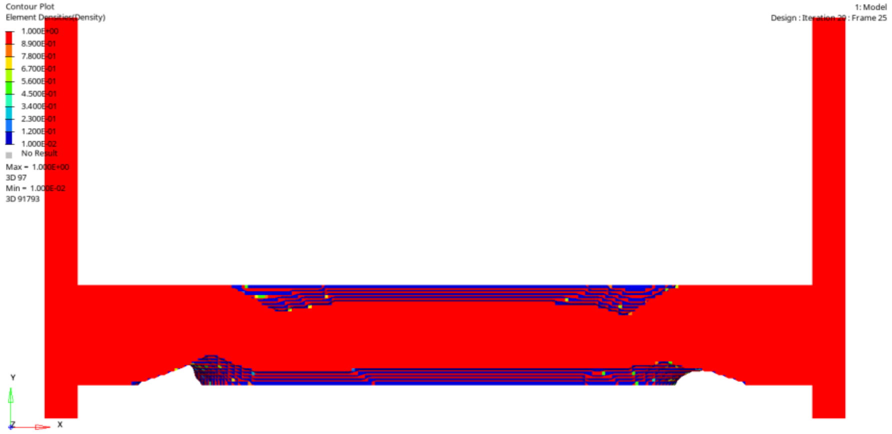
97.79% 감소

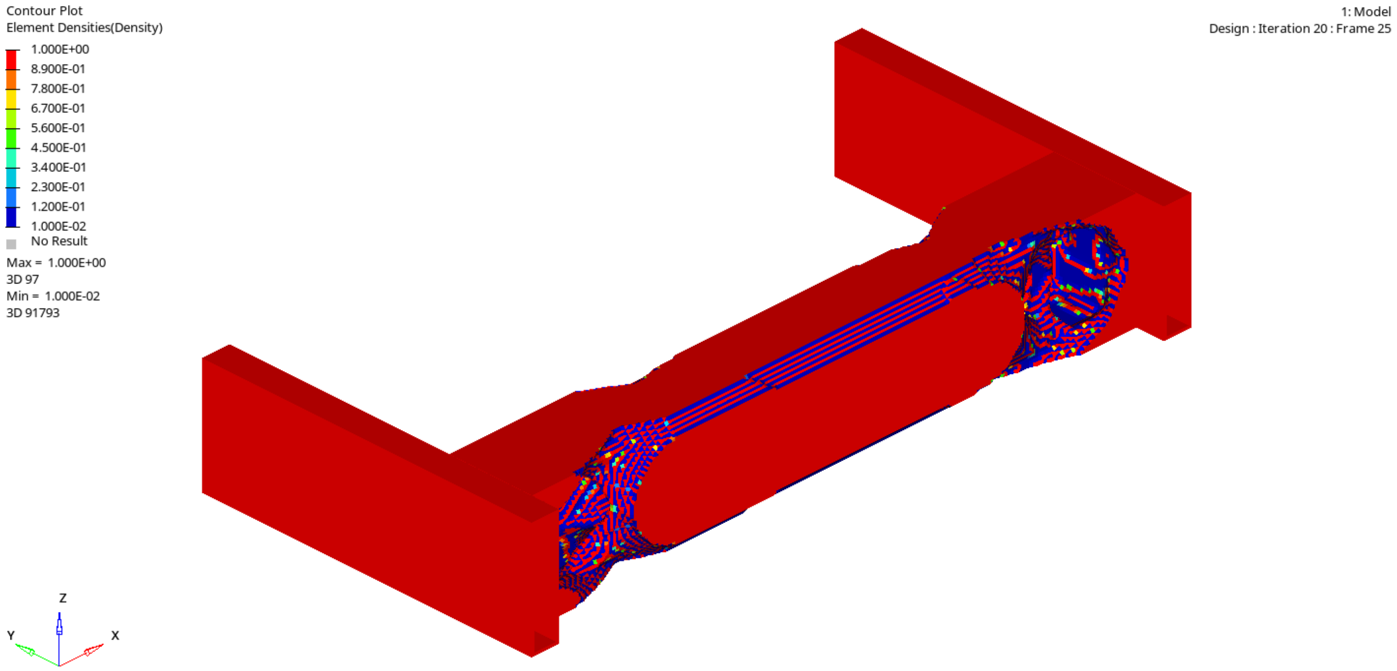
SMTO - Torsion

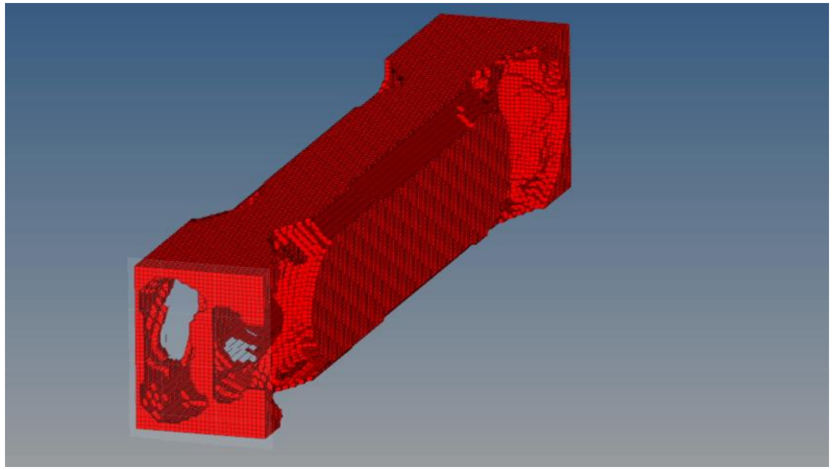


$$\min : C$$
$$s.t : \text{Volume fraction} \le 0.3$$

SMTO - Torsion



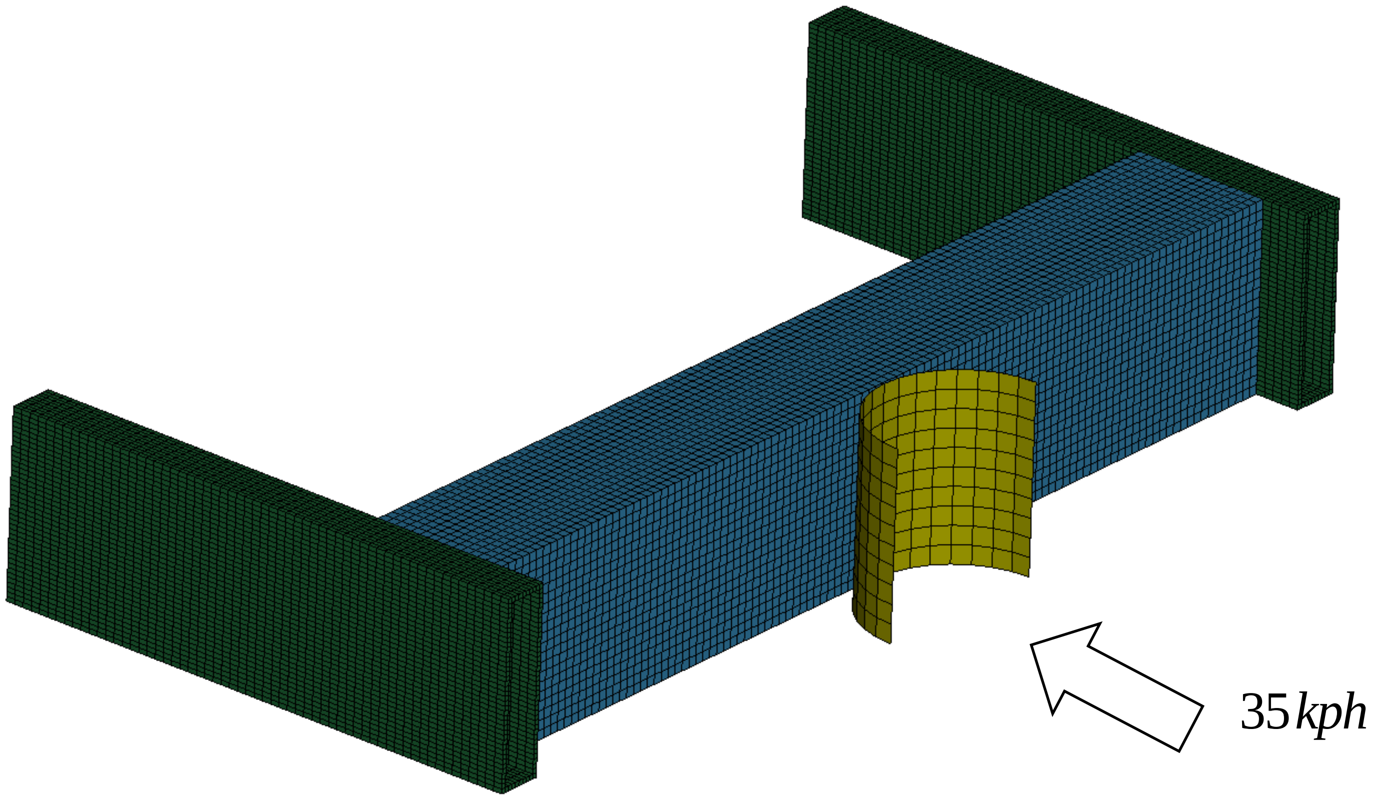




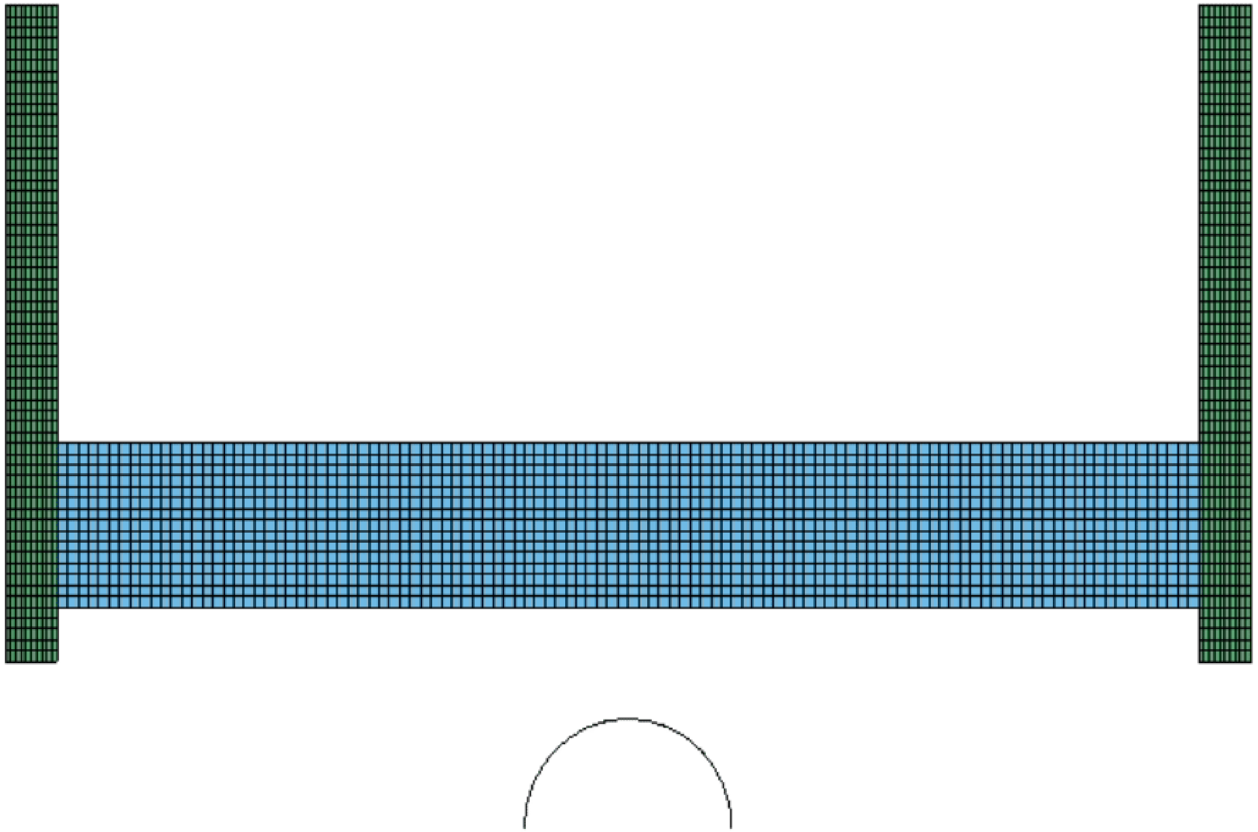
	Compliance [Nmm]	Volume Fraction (Steel)	Mass [kg]
Initial Design	3.40625E+01	0.3	7.772E-02
Optimal Design	2.04965E+01	0.3	7.772E-02

39.8% 감소

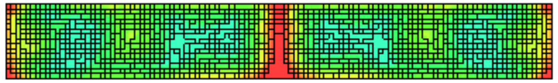
SMTO - Crashworthiness



SMTO - Crashworthiness

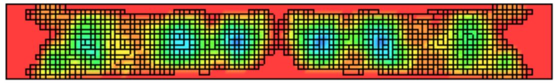


SMTO - Crashworthiness

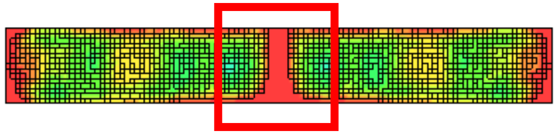


Iter : 4

Iter : 0

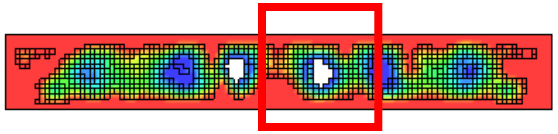


Iter : 11



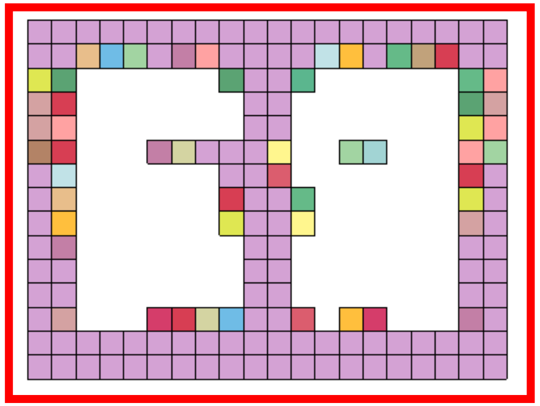
Iter : 7

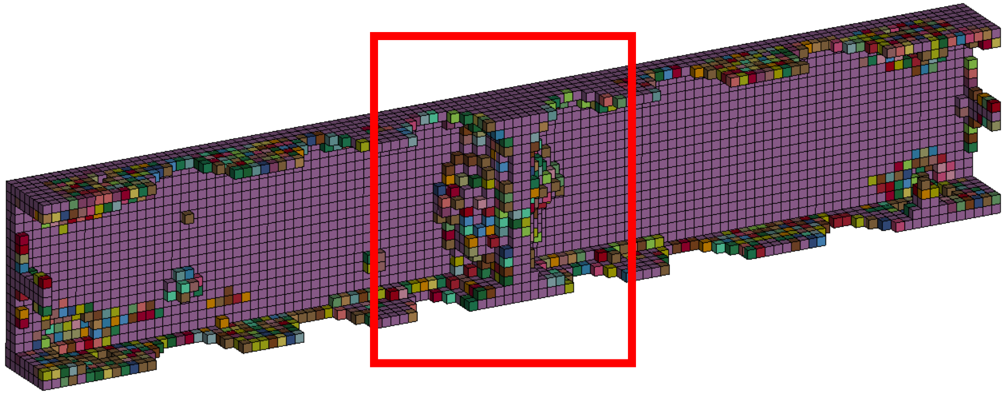
Iter : 18

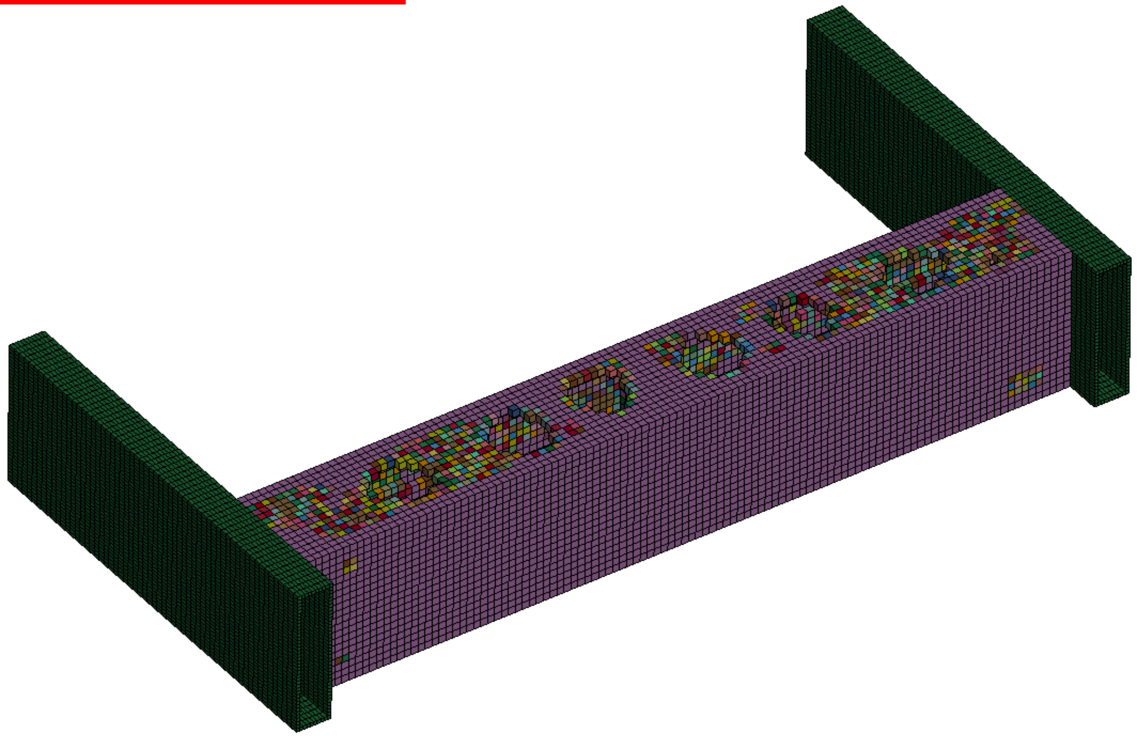


Iter : 14

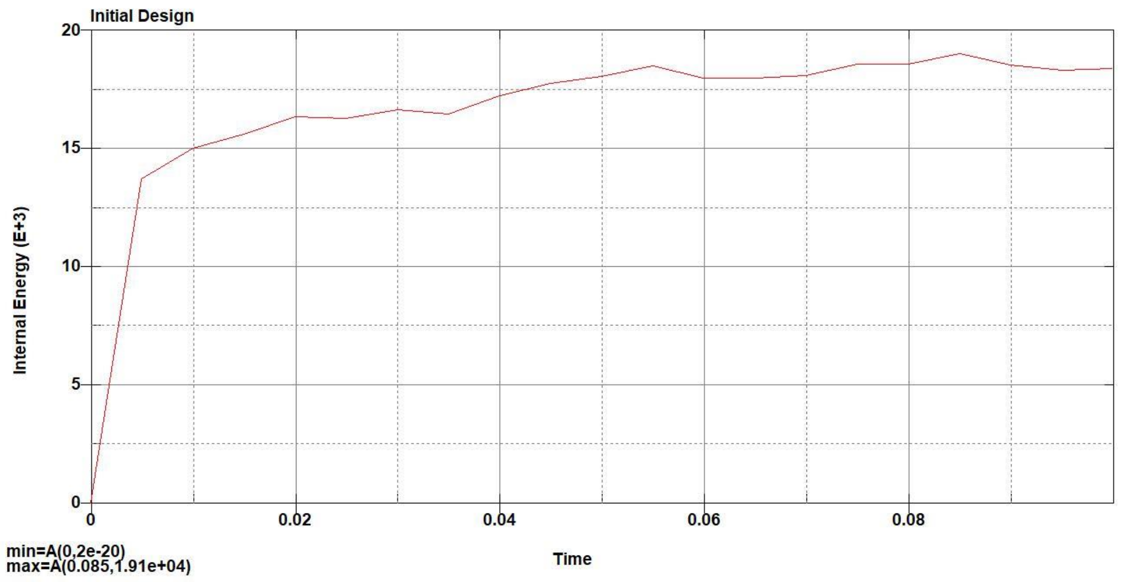
SMTO - Crashworthiness

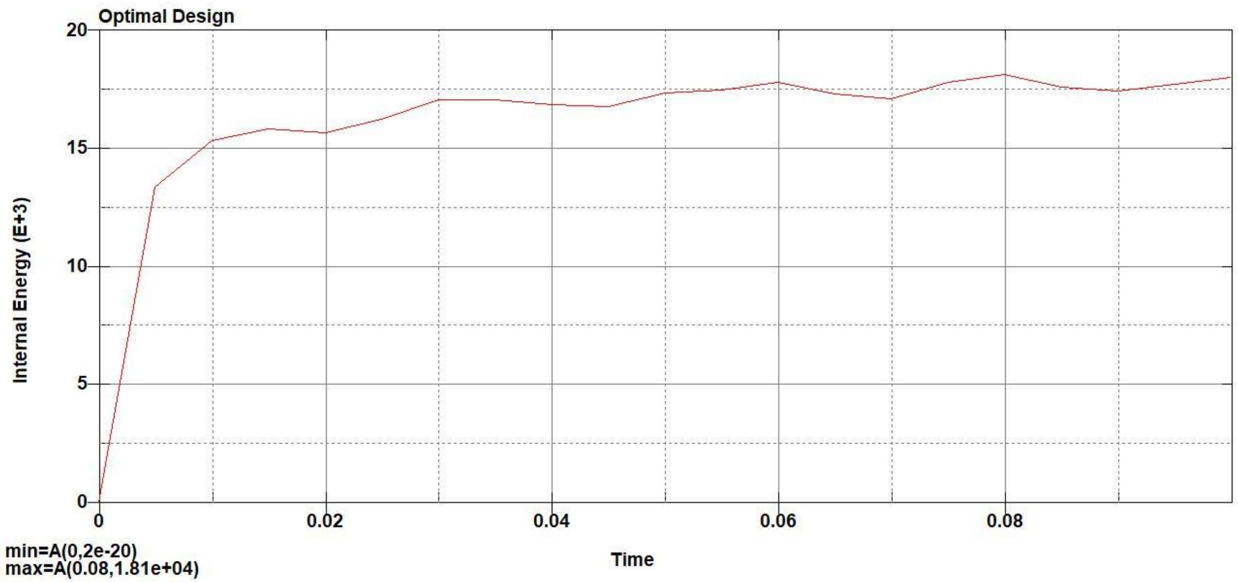






SMTO - Crashworthiness



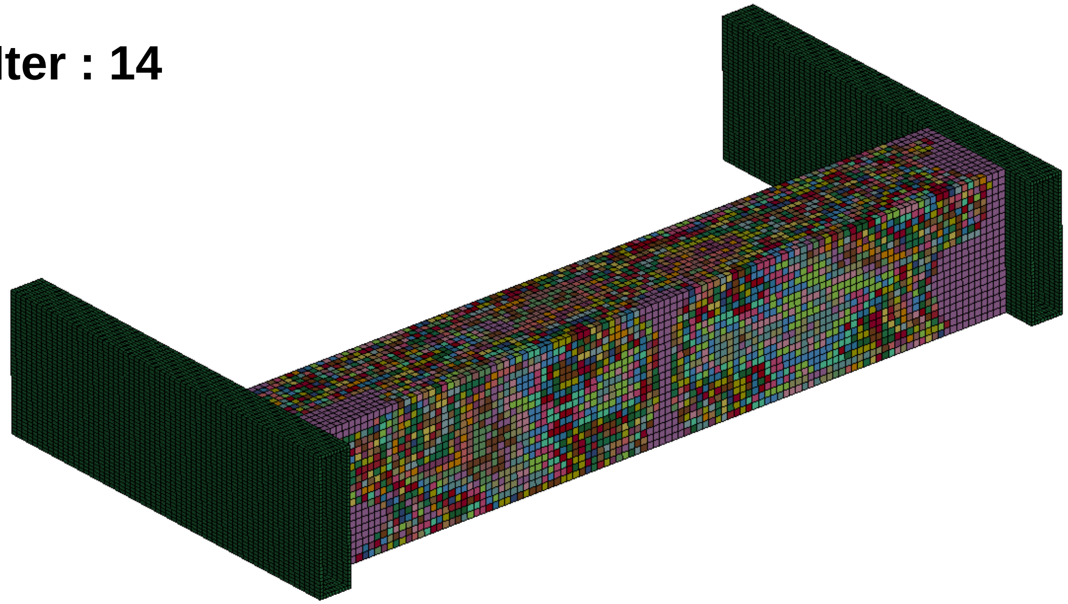


	Compliance (MAX) [Nmm]	Volume Fraction (Steel)	Mass [kg]
Initial Design	1.91E+4	0.3	7.772E-02
Optimal Design	1.81E+4	0.3	7.772E-02

5.2% 감소

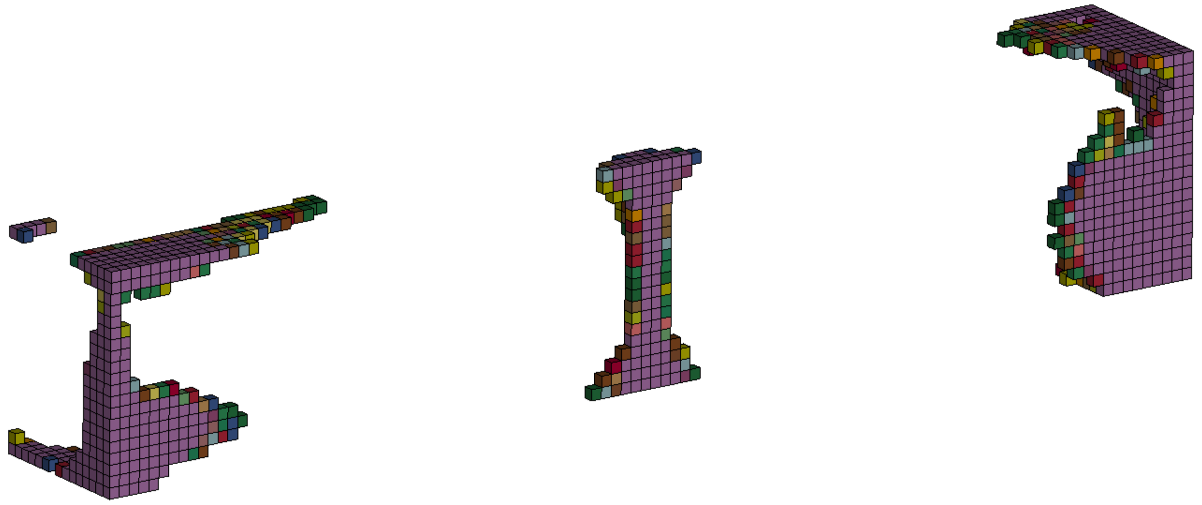
SMTO - Multiple Load Cases

Iter : 14



Load Case Weight

- **Crashworthiness:** 약 50%
- **Torsion:** 약 30%
- **Bending:** 약 20%



$\rho_e \geq 0.8$

Multi-Material Topology Optimization(MMTO)

Computational Design Lab

- **Setting**

$$\min : mass$$
$$s.t : C \le C^*$$

Multiple Mats		steel	1		MAT1
Multiple Materials:	Materials	aluminum	2		MAT1

steel

E:	200000.0
G:	
NU:	0.3
RHO:	7.85e-09

aluminum

E:	70000.0
G:	
NU:	0.32
RHO:	2.7e-09

Solver Keyword:	DESOBJ(MIN)
Name:	objective
ID:	1
Include:	[Main Model]
Objective Type:	Minimize
Response Id:	(2) mass

Bending

$$C^* = 244.9$$

Solver Keyword:	DCONSTR
Name:	comp
ID:	1
Include:	[Main Model]
Response:	(1) comp
List of Loadsteps:	1 Loadsteps
Lower Options:	<OFF>
Upper Options	
Upper Options:	Upper bound
Upper Bound:	244.9

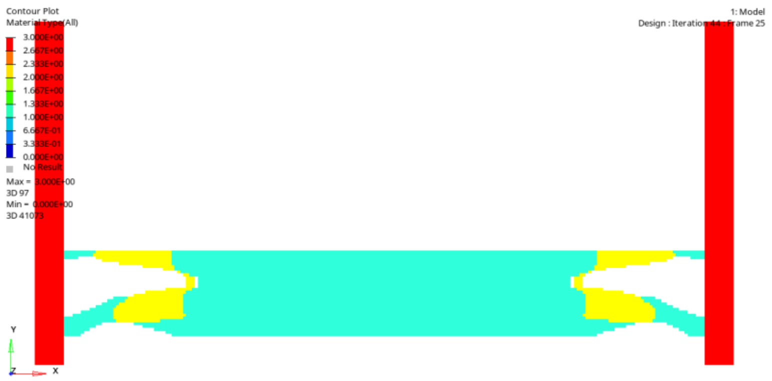
Torsion

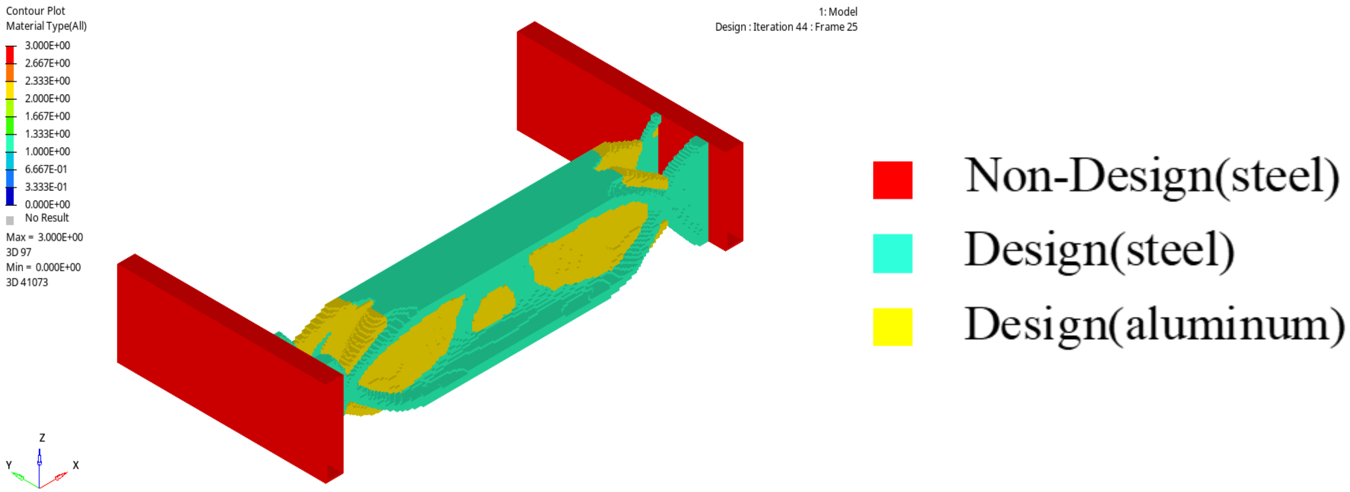
$$C^* = 20.5$$

Solver Keyword:	DCONSTR
Name:	comp
ID:	1
Include:	[Main Model]
Response:	(1) comp
List of Loadsteps:	1 Loadsteps
Lower Options:	<OFF>
Upper Options	
Upper Options:	Upper bound
Upper Bound:	20.5

MMTO - Bending

- **Result**



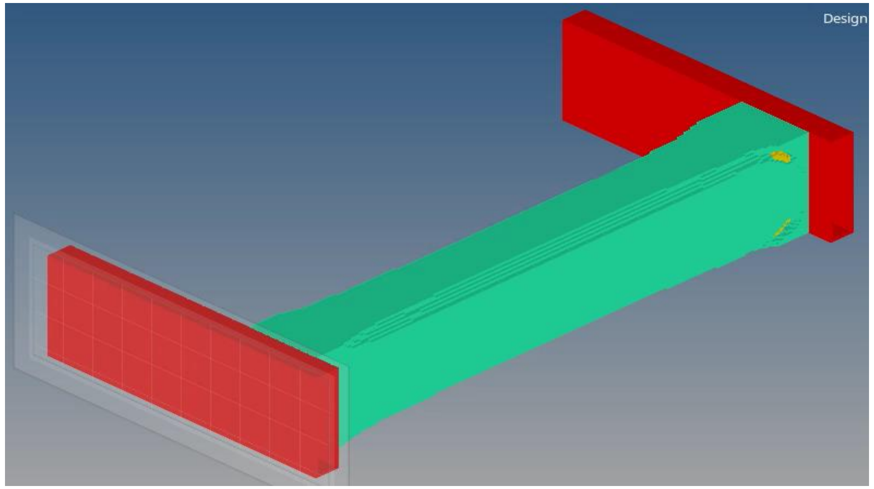


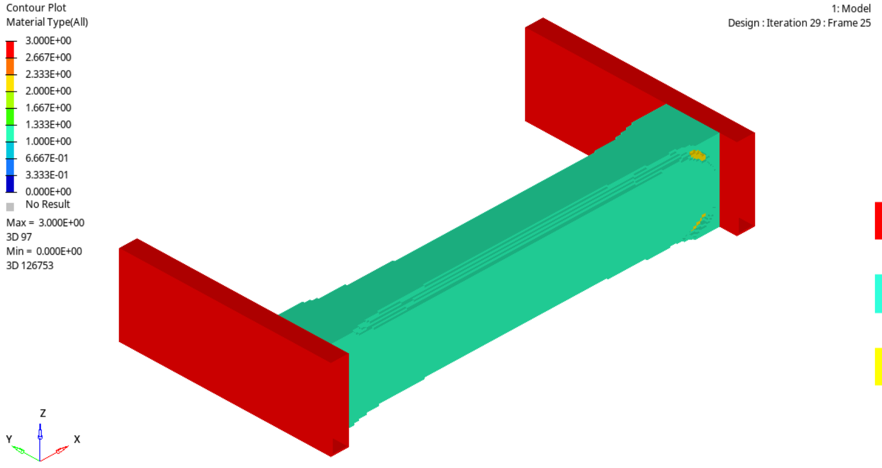
	Compliance [Nmm]	Volume Fraction (Steel)	Volume Fraction (Aluminum)	Mass [kg]
SMTO	2.449E+02	0.3		7.772E-02
MMTO	2.448E+02	0.193	0.136	6.207E-02

↓ 20.1%

MMTO - Torsion

- **Result**

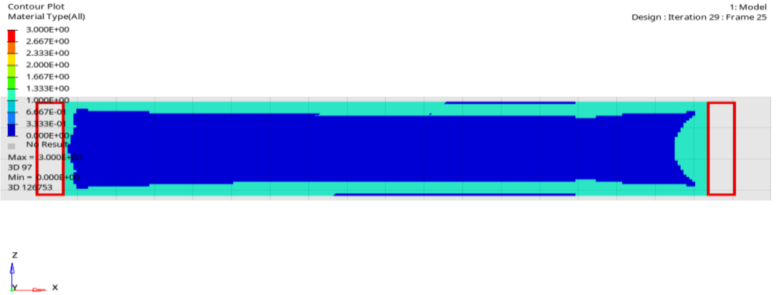




Non-Design(steel)

Design(steel)

Design(aluminum)

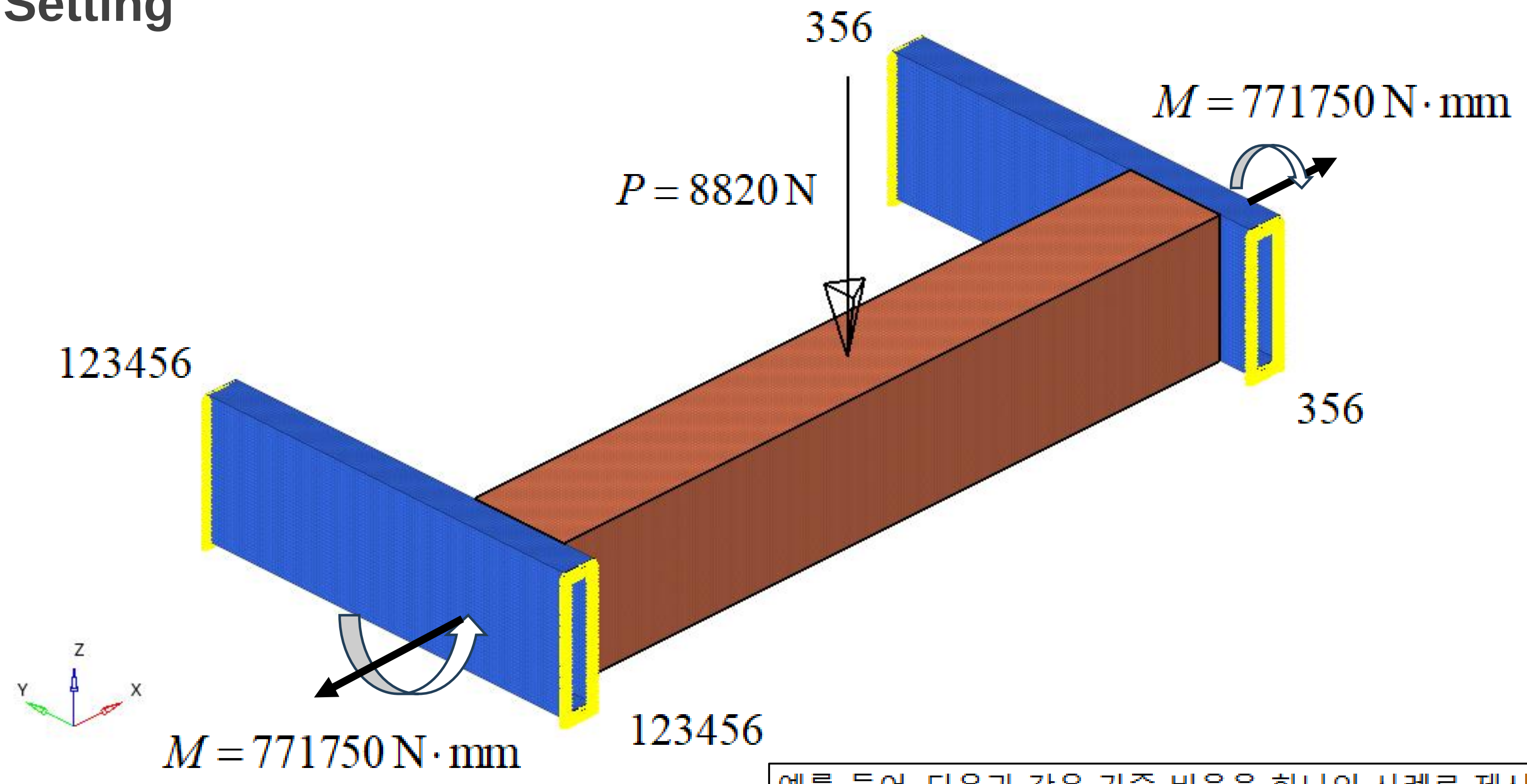


	Compliance [Nmm]	Volume Fraction (Steel)	Volume Fraction (Aluminum)	Mass [kg]
SMTO	2.05E+01	0.3		7.772E-02
MMTO	2.05E+01	0.284	0.008	7.418E-02

↓ 4.6%

SMTO - Multiple load case

- **Setting**



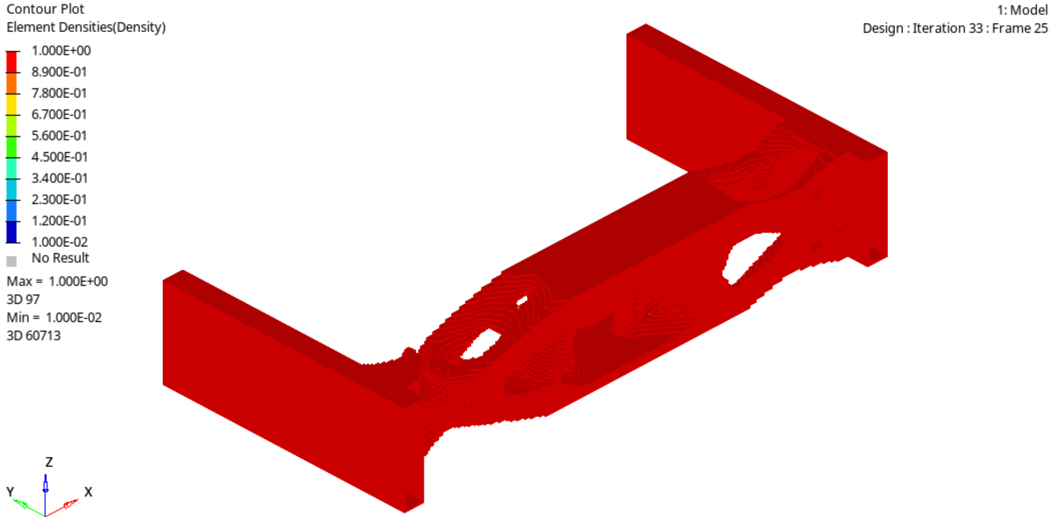
예를 들어, 다음과 같은 가중 비율을 하나의 사례로 제시할 수 있다.

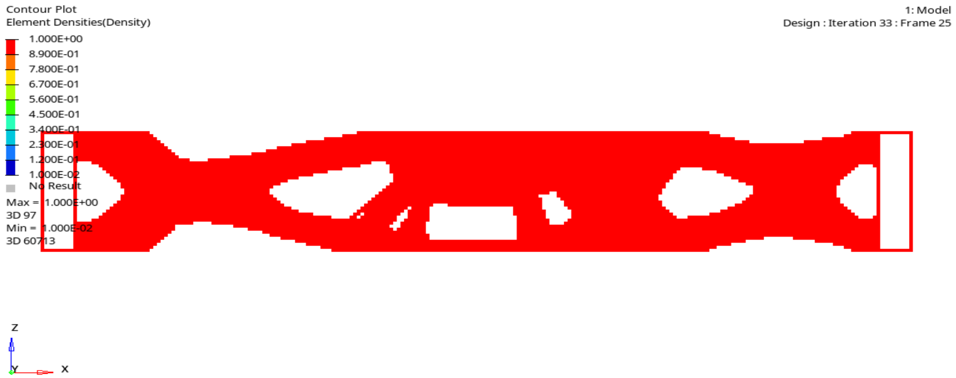
- **Crashworthiness:** 약 50%
- **Torsion:** 약 30%
- **Bending:** 약 20%

	Loadstep ID	Weight
1	2	3
2	1	2

SMTO - Multiple load case

- **Result**



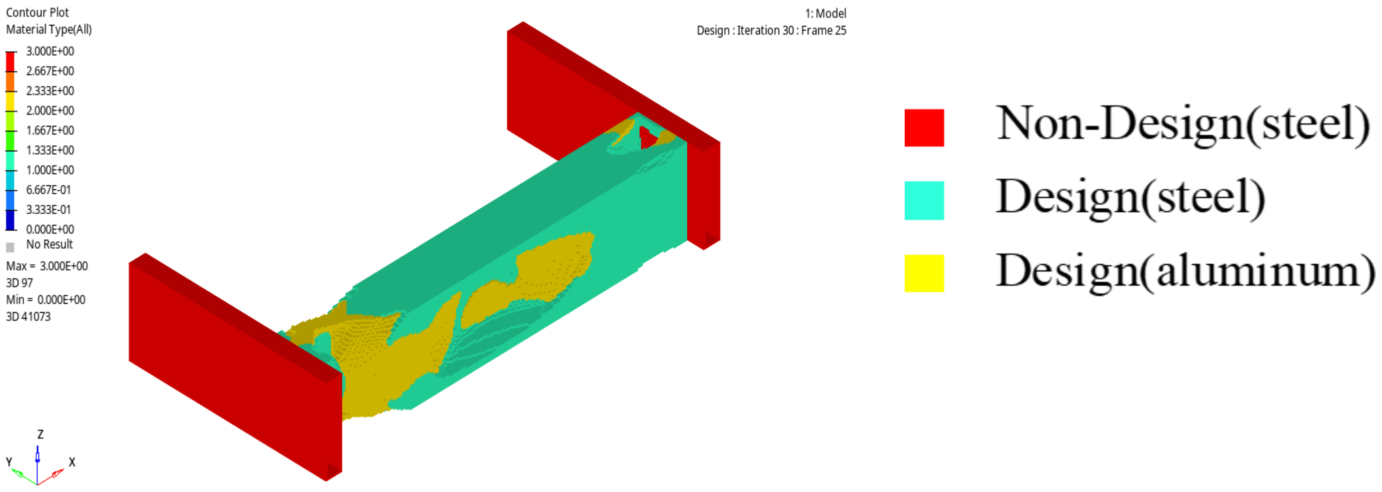


$$C^* = 584.7$$

Solver Keyword:	DCONSTR
Name:	comp
ID:	1
Include:	[Main Model]
⊞ Response:	(1) comp
Lower Options:	<OFF>
⊟ **Upper Options**	
Upper Options:	Upper bound
Upper Bound:	584.7

MMTO - Multiple load case

- **Result**

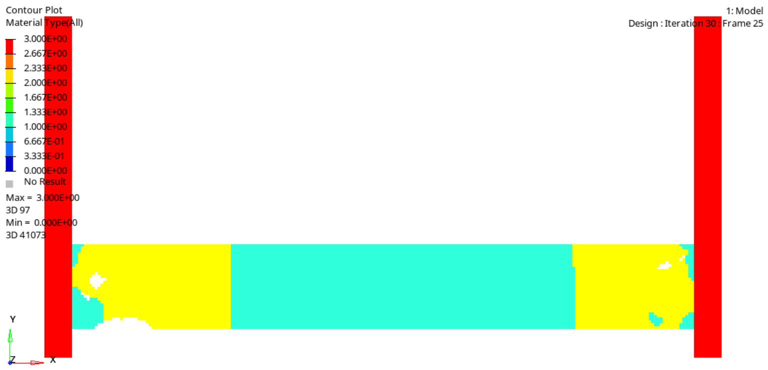


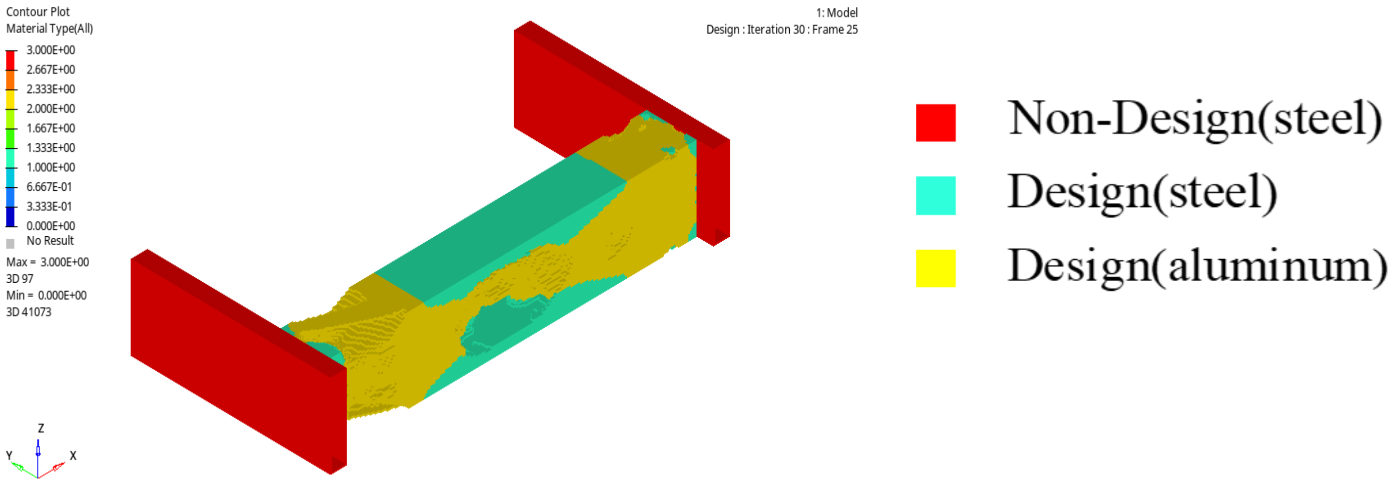
	Compliance [Nmm]	Volume Fraction (Steel)	Volume Fraction (Aluminum)	Mass [kg]
SMTO	5.847E+02	0.3		7.772E-02
MMTO	5.843E+02	0.219	0.116	6.698E-02

↓13.8%

MMTO - Multiple load case

- **Result**





	Initial Value (Steel)	Volume Fraction (Steel)	Initial Value (Aluminum)	Volume Fraction (Aluminum)	Mass [kg]
MATINIT=Default	0.5	0.219	0.5	0.116	6.698E-02
MATINIT=0.3	0.3	0.156	0.3	0.358	7.245E-02

Future Work

- Manufacturability of MMTO
- MMTO + Crashworthiness
- Link with Other Program (ex. Hypermesh + Matlab)

Thank you

Computational Design Lab