

# Body Torsional Analysis

Computational Design Laboratory  
Department of Automotive Engineering  
Hanyang University, Seoul, Korea



# OUTLINE

- **Lecture Goals**

- ✓ Side frame모델(bean)의 유효전단강성과 passenger cabin모델 (beam+shell)의 비틀림 강성을 계산하여 이론해와 비교한다.

- **Contents**

- ✓ **Body torsional stiffness analysis #1**

- : Beam elements

- ✓ **Body torsional stiffness analysis #2**

- : Shell + beam elements

# Body Torsional Stiffness Analysis

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# 목차

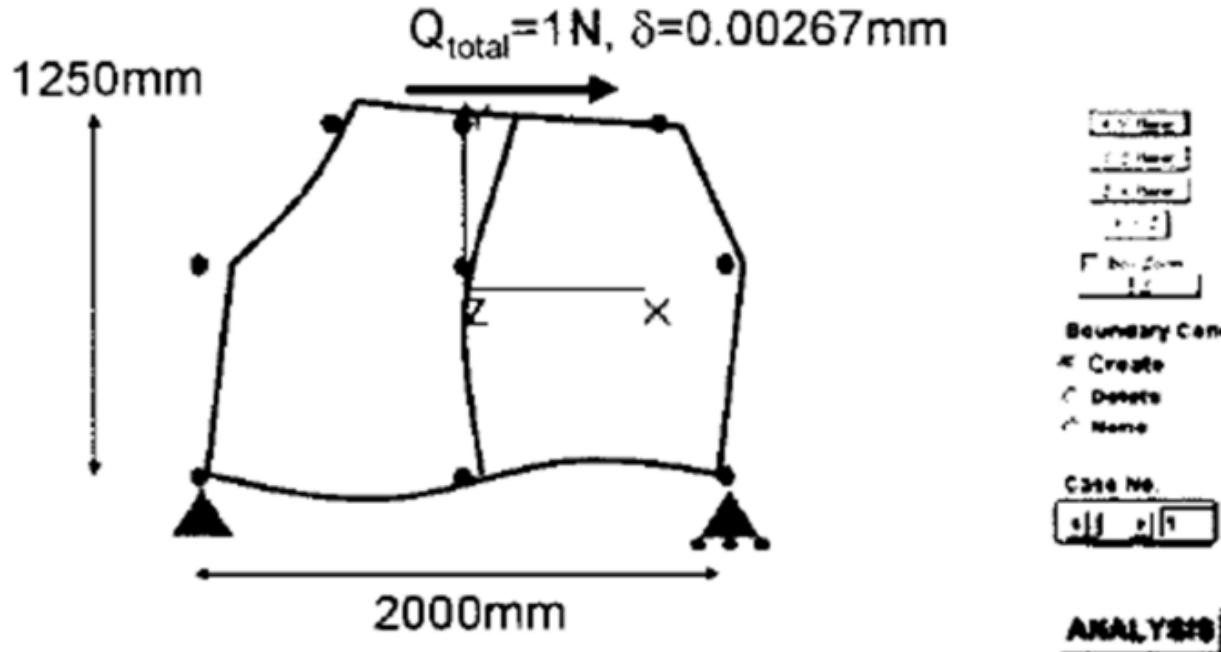
- 예제 문제
  - Effective shear stiffness analysis of side frame
  - Body torsional stiffness analysis
- 해석 프로세스
  - 기하형상 생성
  - 재료 물성 및 특성 입력
  - 요소망 생성
  - 구속조건 설정
  - 하중조건 설정
  - 해석케이스 정의 및 해석 실행
  - 후처리

# EFFECTIVE SHEAR RIGIDITY (SIDE FRAME)

# 예제: TORSIONAL STIFFNESS (3)

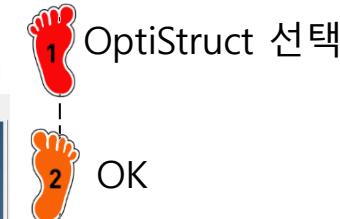
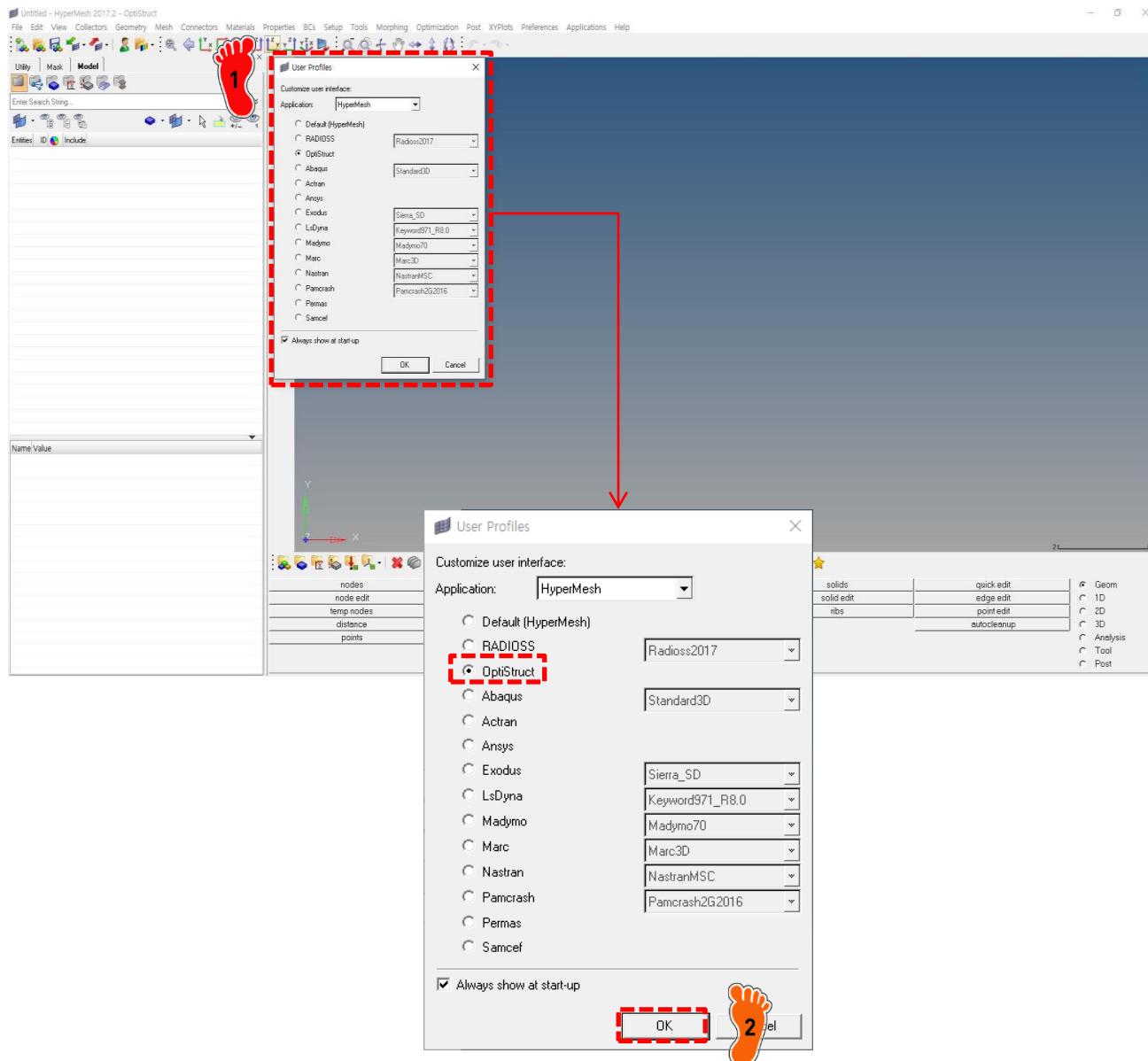
Side Frame Model 의 강성 계산

- FEA under shear loading

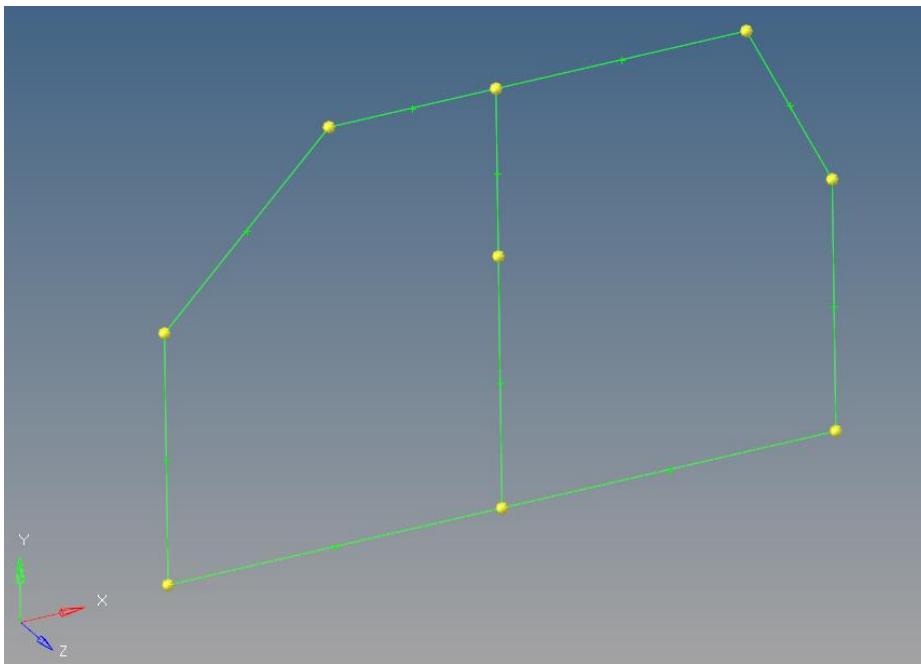
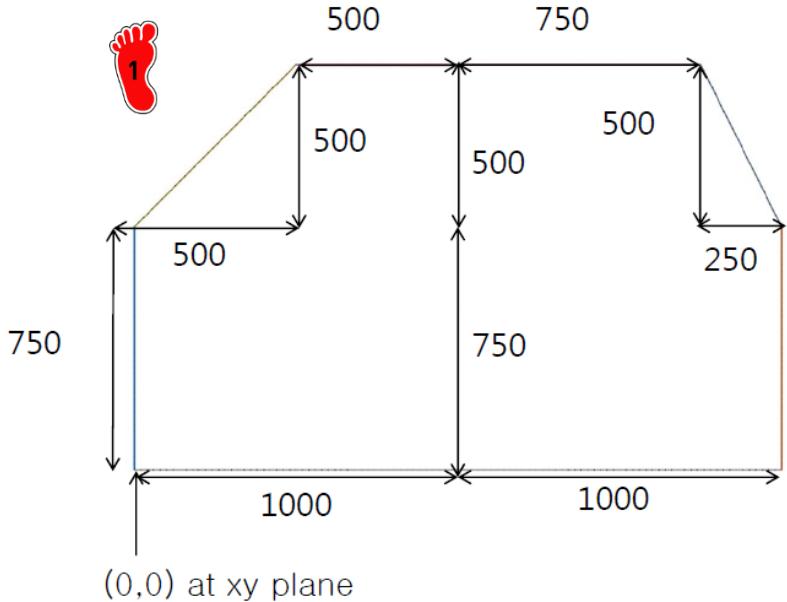


$$(Gt)_{\text{Eff}} = \left( \frac{Q}{\delta} \right) \frac{H}{L} = \left( \frac{1\text{N}}{0.00267\text{mm}} \right) \frac{1250\text{mm}}{2000\text{mm}} = 234\text{N/mm}$$

# 기하형상 생성 (1)



# 기하형상 생성 (2)

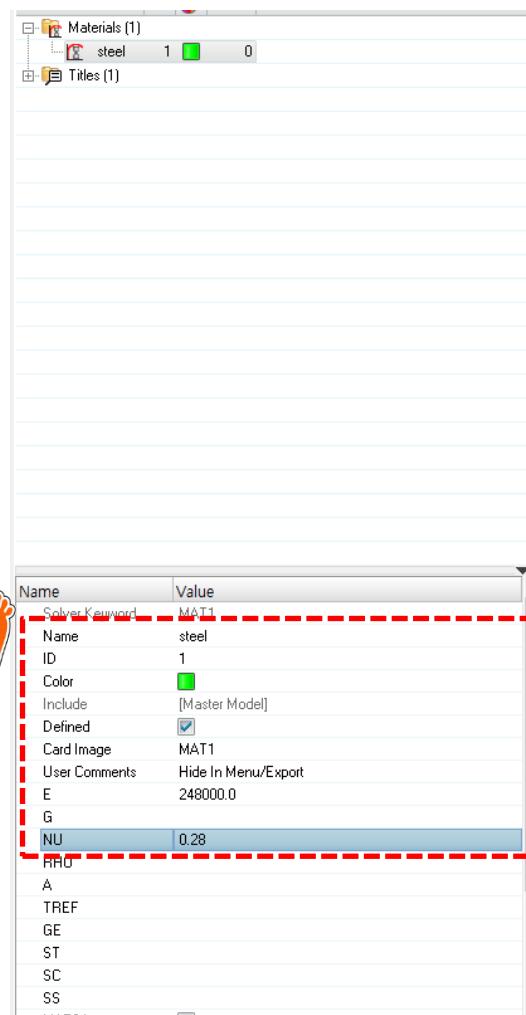
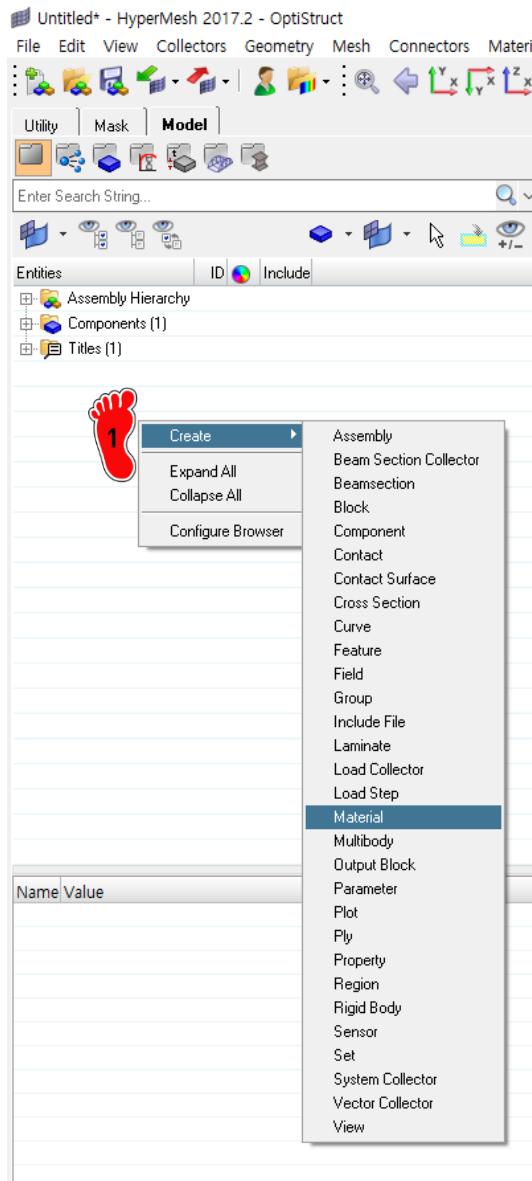


1 주어진 기하형상 생성

좌표(x,y,z)

(0,0,0)  
(0,750,0)  
(500,1250,0)  
(1000,0,0)  
(1000,750,0)  
(1000,1250,0)  
(1750,1250,0)  
(2000,0,0)  
(2000,750,0)

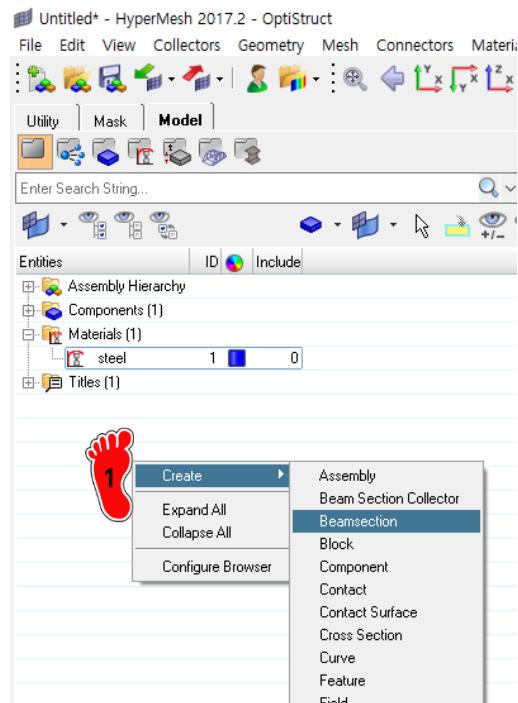
# 재료 물성 및 특성 입력 (1)



1 우클릭, Create > Material

2 Name > steel  
탄성계수(E)  
> 248 Gpa (248000 N/mm<sup>2</sup>)  
푸아송비(NU) > 0.28  
재료 생성

# 재료 물성 및 특성 입력 (2)

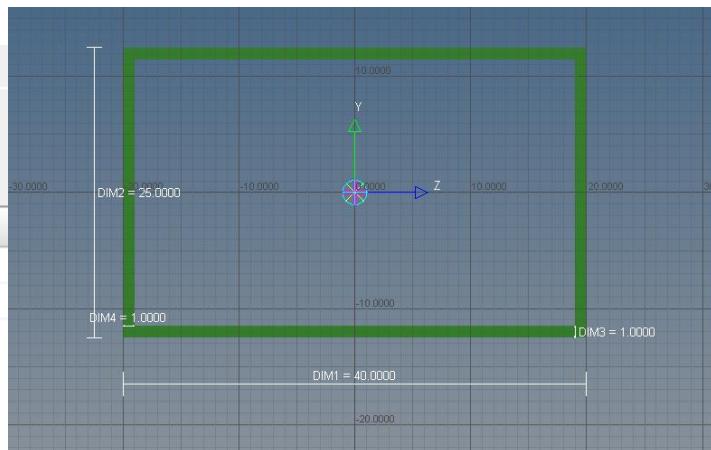
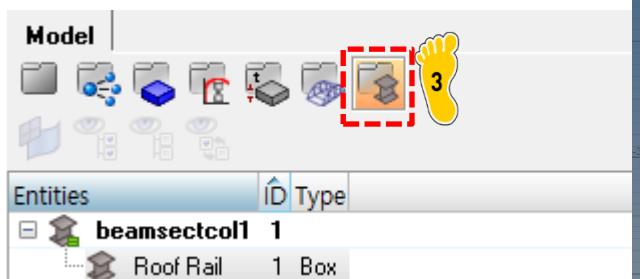


Name	Value
Name	Roof Rail
ID	1
Include	[Master Model]
Collector	(1) beamsectcol1
Config	Standard
2 Section Type	BOX
<b>Parameter Definitions</b>	
Dimension DIM1	40.0
Dimension DIM2	25.0
Thickness DIM3	1.0
Thickness DIM4	1.0

1 우클릭,  
Create > Beamsection

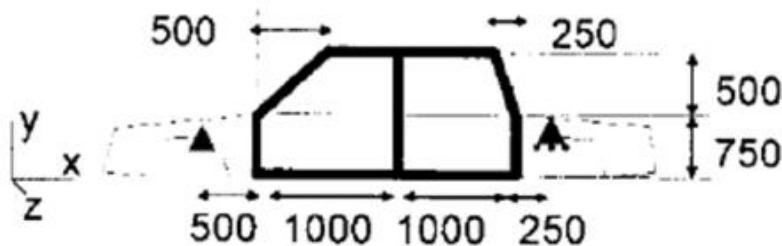
2 Section Type > BOX,  
단면형상 입력

3 Hyperbeam view에서 단면  
형상 확인 가능



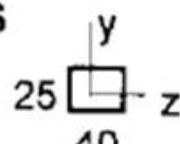
# 재료 물성 및 특성 입력 (3)

**Sideframe Dimensions  
(all in mm)**

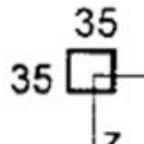


## SECTIONS

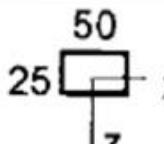
(t=1mm)



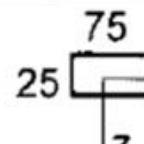
Roof Rail



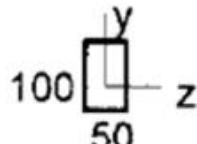
A Pillar



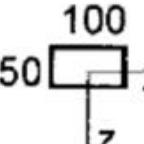
B Pillar  
above Belt



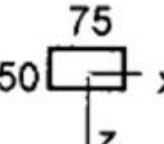
C Pillar  
above Belt



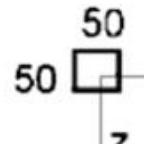
Rocker



Hinge  
Pillar



B Pillar  
Below Belt



C Pillar  
Below Belt



1 예제에서 주어진 단면형상 8개를 각각 생성



2 Dimension DIM1에 Z방향 길이 입력

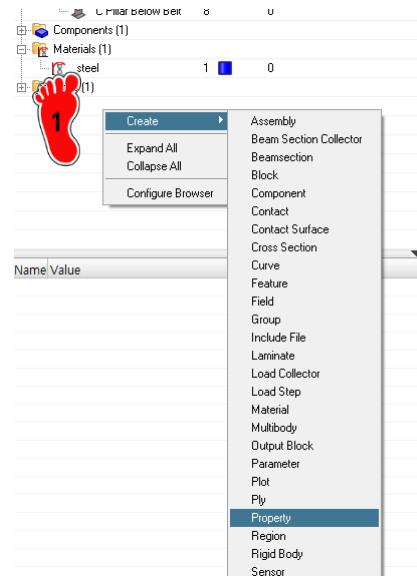
Assembly Hierarchy		
Beam Section Collectors (1)		
beamsectcoll	1	0
Roof Rail	1	0
A Pillar	2	0
B Pillar above Belt	3	0
C Pillar above Belt	4	0
Rocker	5	0
Hinge Pillar	6	0
B Pillar Below Belt	7	0
C Pillar Below Belt	8	0

Name	Value
Name	Roof Rail
ID	1
Include	[Master Model]
Collector	(1) beamsectcoll
Config	Standard
Section Type	BOX
Parameter Definitions	
Dimension DIM1	40.0
Dimension DIM2	25.0
Thickness DIM3	1.0
Thickness DIM4	1.0



2 Dimension DIM1에 Z방향 길이 입력

# 재료 물성 및 특성 입력 (4)



Entities	ID	Color	Include
<b>Beam Section Collectors (1)</b>			
beamsectcol1	1	0	
Roof Rail	1	0	
A Pillar	2	0	
B Pillar above Belt	3	0	
C Pillar above Belt	4	0	
Rocker	5	0	
Hinge Pillar	6	0	
B Pillar Below Belt	7	0	
C Pillar Below Belt	8	0	
<b>Components (1)</b>			
<b>Materials (1)</b>			
steel	1	blue	0
<b>Properties (8)</b>			
Roof Rail	1	light blue	0
A Pillar	2	magenta	0
B Pillar above Belt	3	red	0
C Pillar above Belt	4	dark red	0
Rocker	5	blue	0
Hinge Pillar	6	dark blue	0
B Pillar Below Belt	7	orange	0
C Pillar Below Belt	8	brown	0

1 우클릭,  
Create > Property

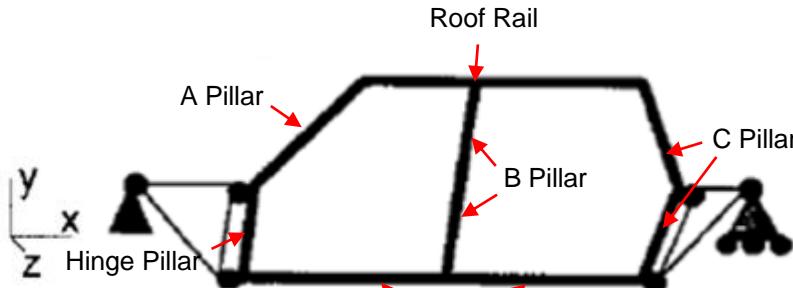
2 Property 8개 각각 생성, 단면 형상과 각각 연결  
Card Image > PBEAM  
Material > steel  
Beam Section > 단면형상  
각각 선택  
Name > 단면 형상과 동일  
하게

2

Name	Value
Solver Keyword	PBEAM
Name	Roof Rail
ID	1
Color	light blue
Include	[Master Model]
Defined	<input checked="" type="checkbox"/>
Card Image	PBEAM
Material	(1) steel
User Comments	Hide In Menu/Export
Beam Section	(1) Roof Rail
PBEAM_CARD3 =	0

# 요소망 생성 (1)

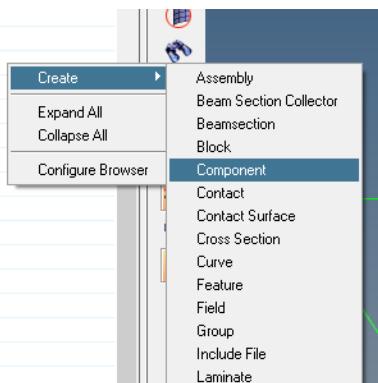
**Sideframe Dimensions**  
(all in mm)



## SECTIONS

(t=1mm)

	y	z	x	z	x	z	x	z
Roof Rail	25	40	35	35	25	50	25	75
A Pillar								
B Pillar above Belt								
C Pillar above Belt								
Rocker	100	50						
Hinge Pillar			100	50	75	50	50	50
B Pillar Below Belt								
C Pillar Below Belt								



Name	Value
Name	Roof Rail
ID	2
Color	[Blue]
Include	[Master Model]
Property	(1) Roof Rail
Material	(1) steel

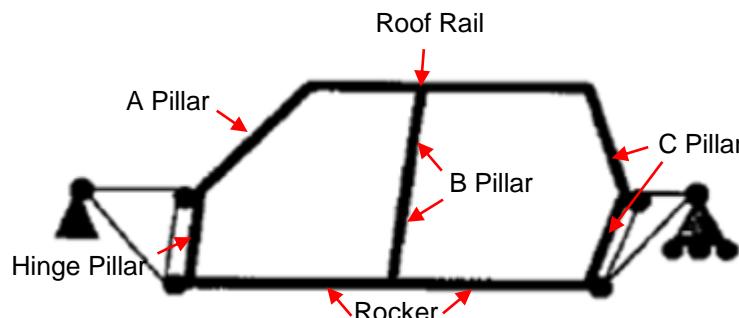
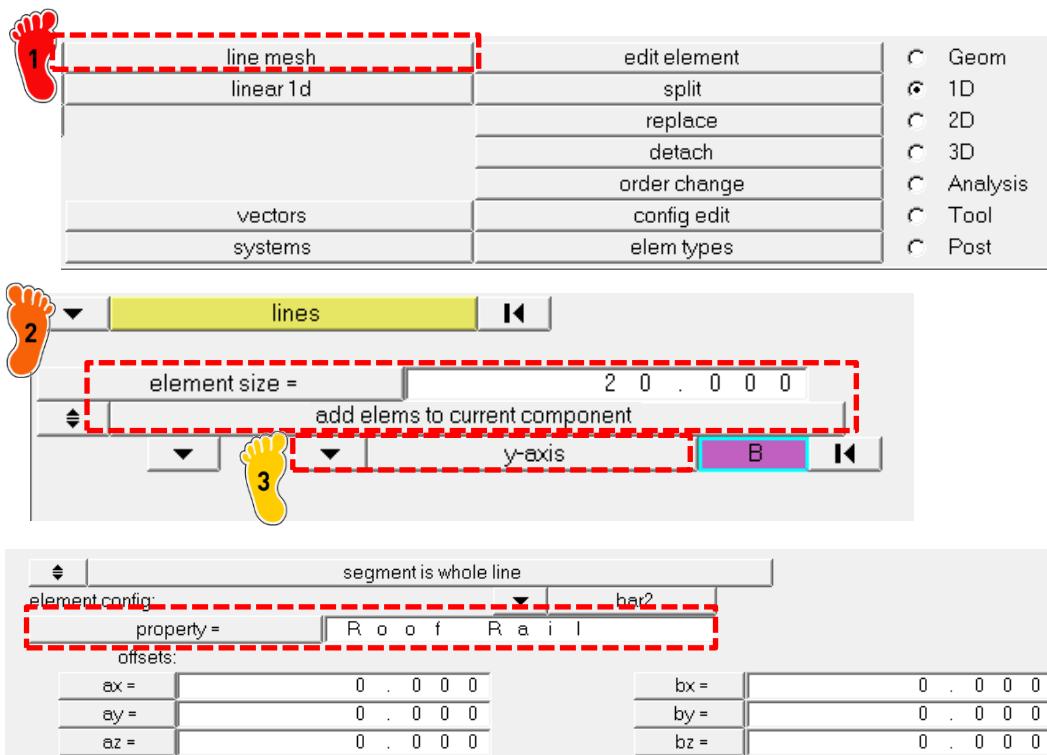


1 우클릭,  
Create > Component



2 Name, Property  
>요소망 생성할 단면형상의  
이름과 동일하게

# 요소망 생성 (2)



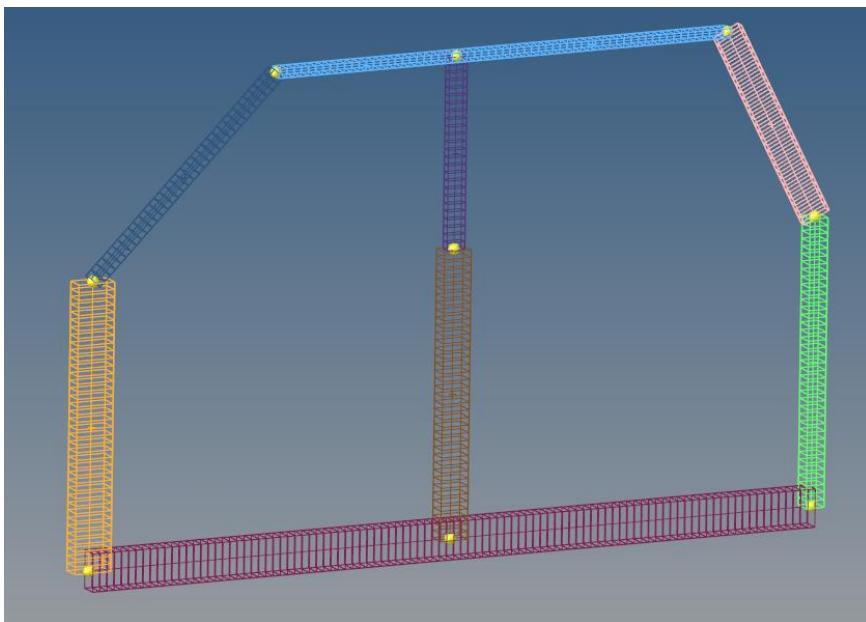
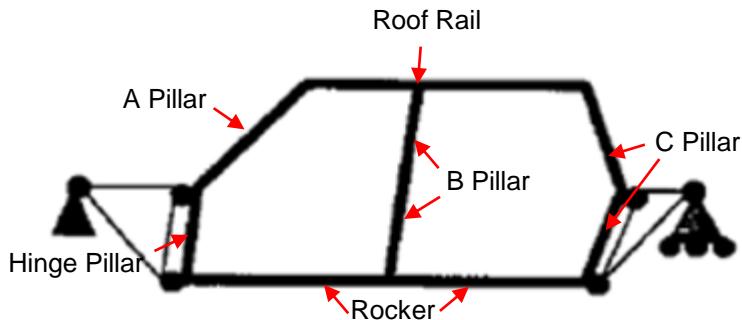
1 1D > line mesh 클릭

2 요소망 생성  
크기 > 20  
Add elems to current  
component  
Property > 단면형상 이름  
과 동일하게

3 요소망 생성시 단면 형상이  
원하는 좌표축에 놓이도록  
주의(x축과 평행한 빔은 y-  
aixs로 선택, y축과 평행한  
빔은 x-aixs로 선택)

4 Mesh,  
Return

# 요소망 생성 (3)



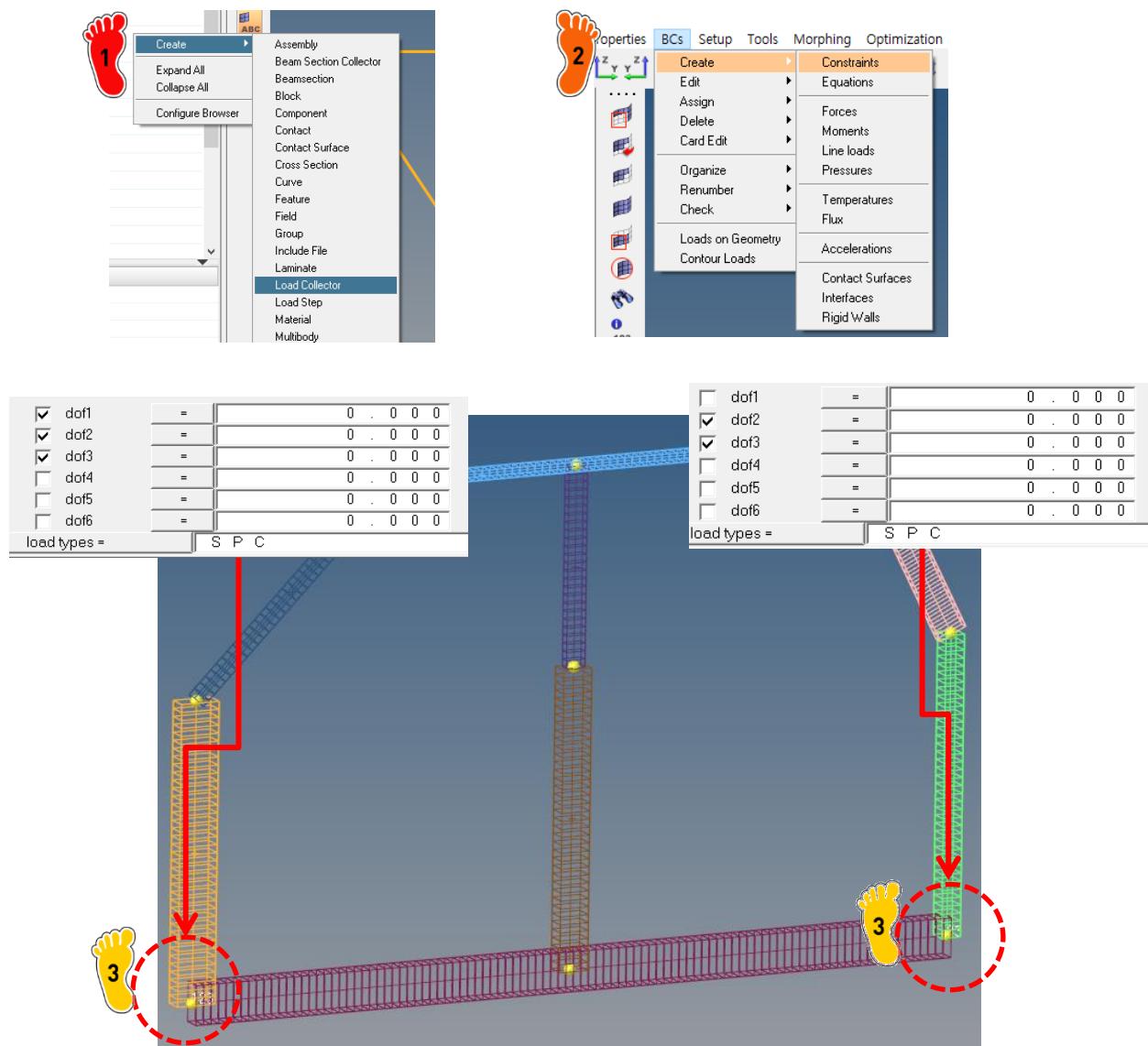
1 앞의 과정(1,2) 반복해서  
8개 빔 요소망 생성

그림과 비슷한 형상이 나와  
야 함

\* Tool -> edges ->  
tolerance -> equivalence  
(모서리 병합)

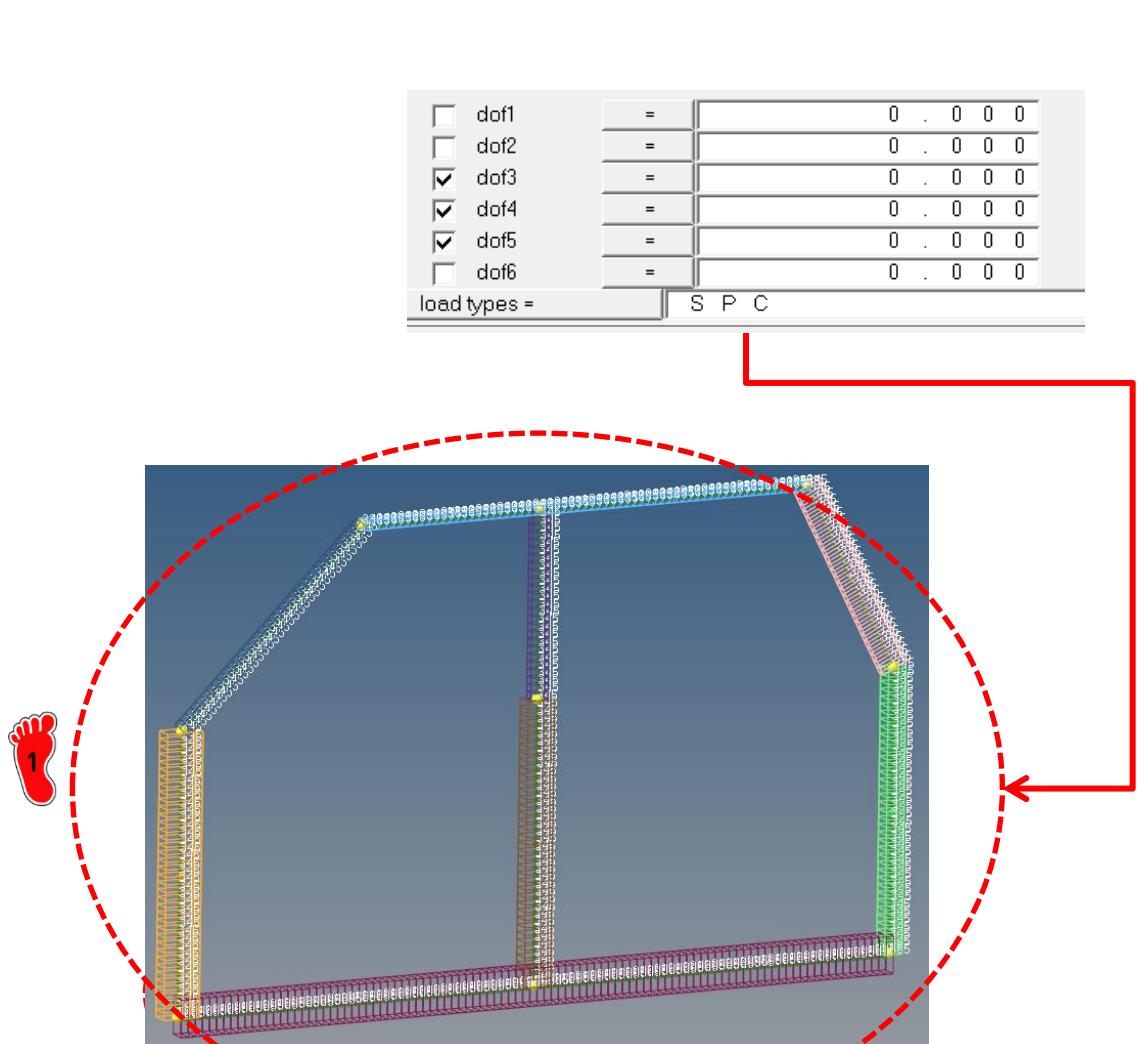
\* Geom -> temp nodes ->  
clear all (Nodes 제거)

# 구속조건 및 하중조건 설정 (1)



- 1 Create > Load Collector  
Name > spc
- 2 BCs > Create  
> Constraints
- 3 좌측 dof1,2,3 check  
Create  
우측 dof2,3 check  
Create

# 구속조건 및 하중조건 설정 (2)



1 나머지는 평면 거동을 위해  
z방향 병진운동, x,y 방향 회  
전운동 구속  
(dof3,4,5)

# 구속조건 및 하중조건 설정 (3)

**1** Create > Load Collector  
Name > Force

**2** BCs > Create > Forces

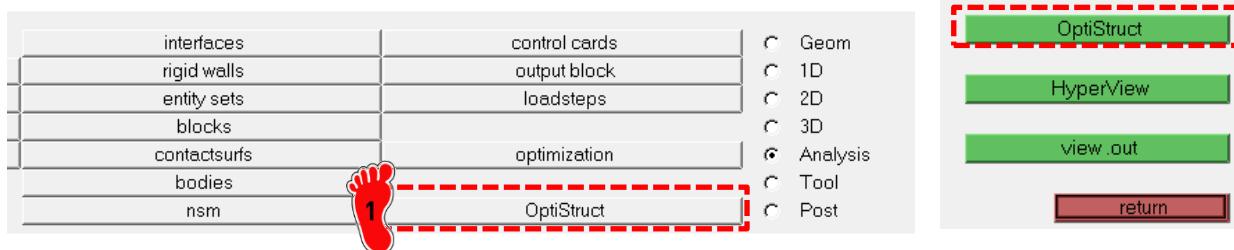
**3** 상단에 X방향으로 0.0156N  
Create (1N/64개 노드)

**4** Create > Load Step

**5** Analysis type  
> Linear Static  
SPC > spc  
LOAD > Force

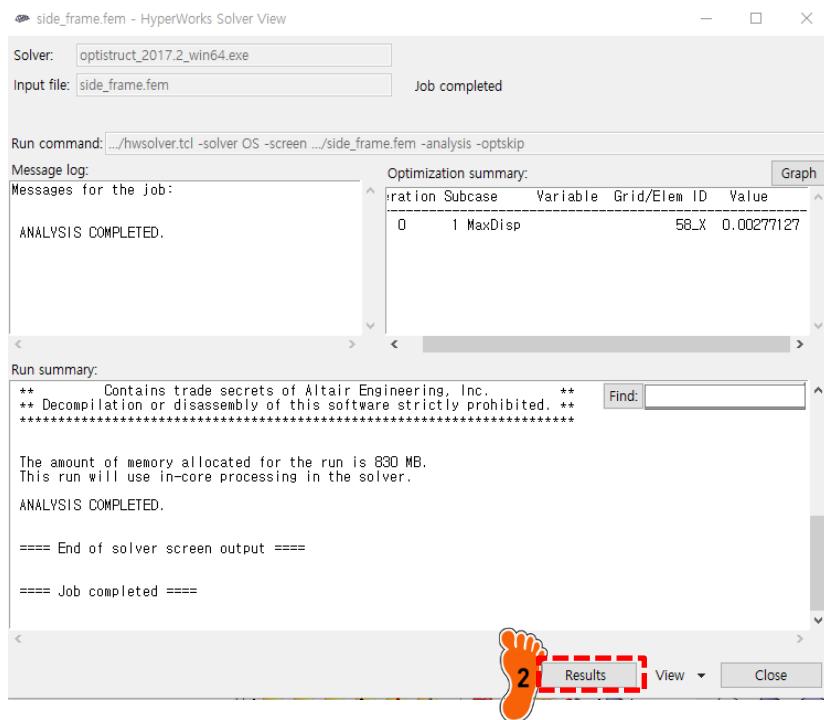
Copyright © Computational Design Lab. All rights reserved.

# 해석 케이스 정의 및 해석 실행

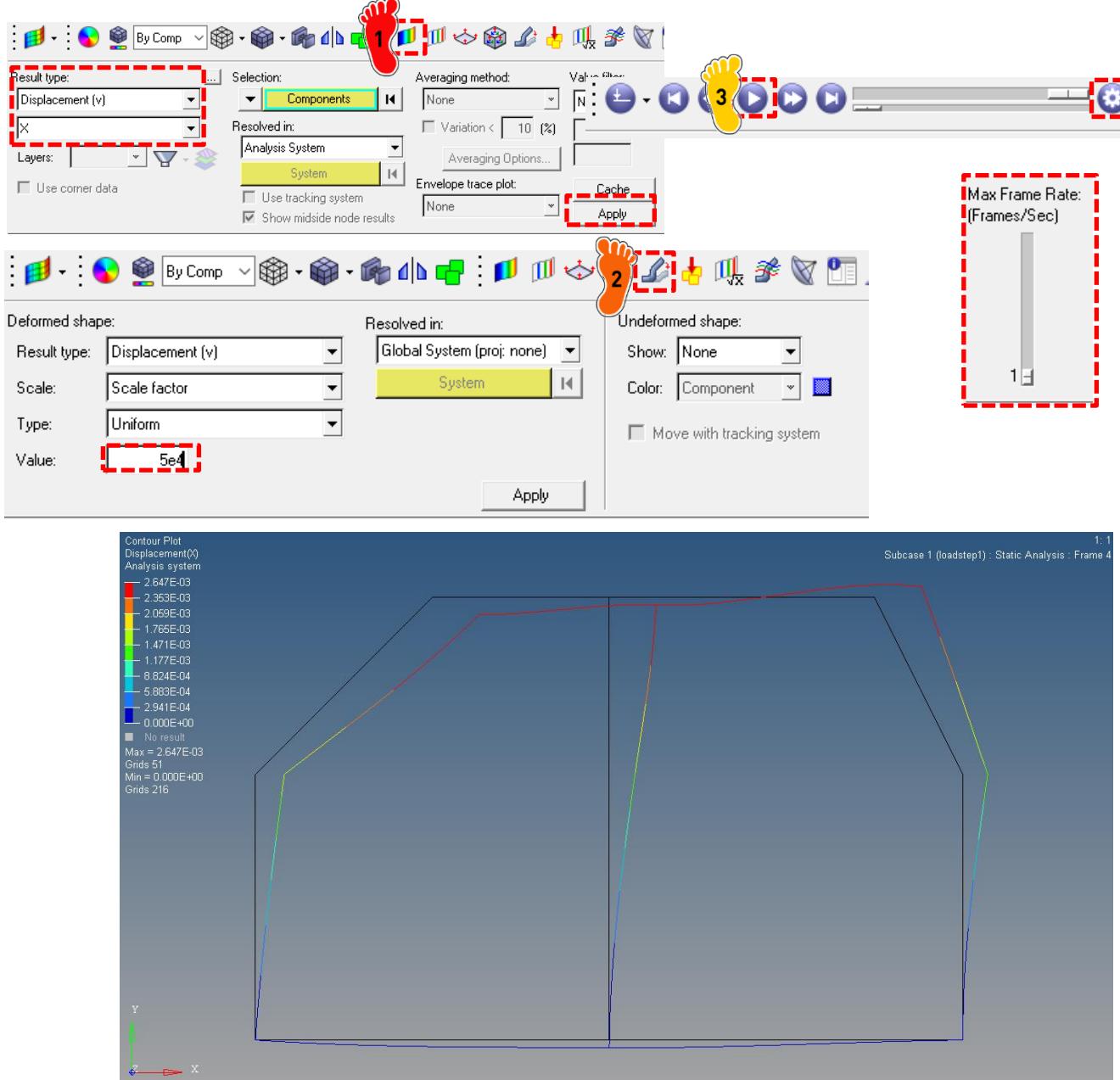


1 Analysis > OptiStruct 클릭  
OptiStruct

2 Results 클릭



# 후처리

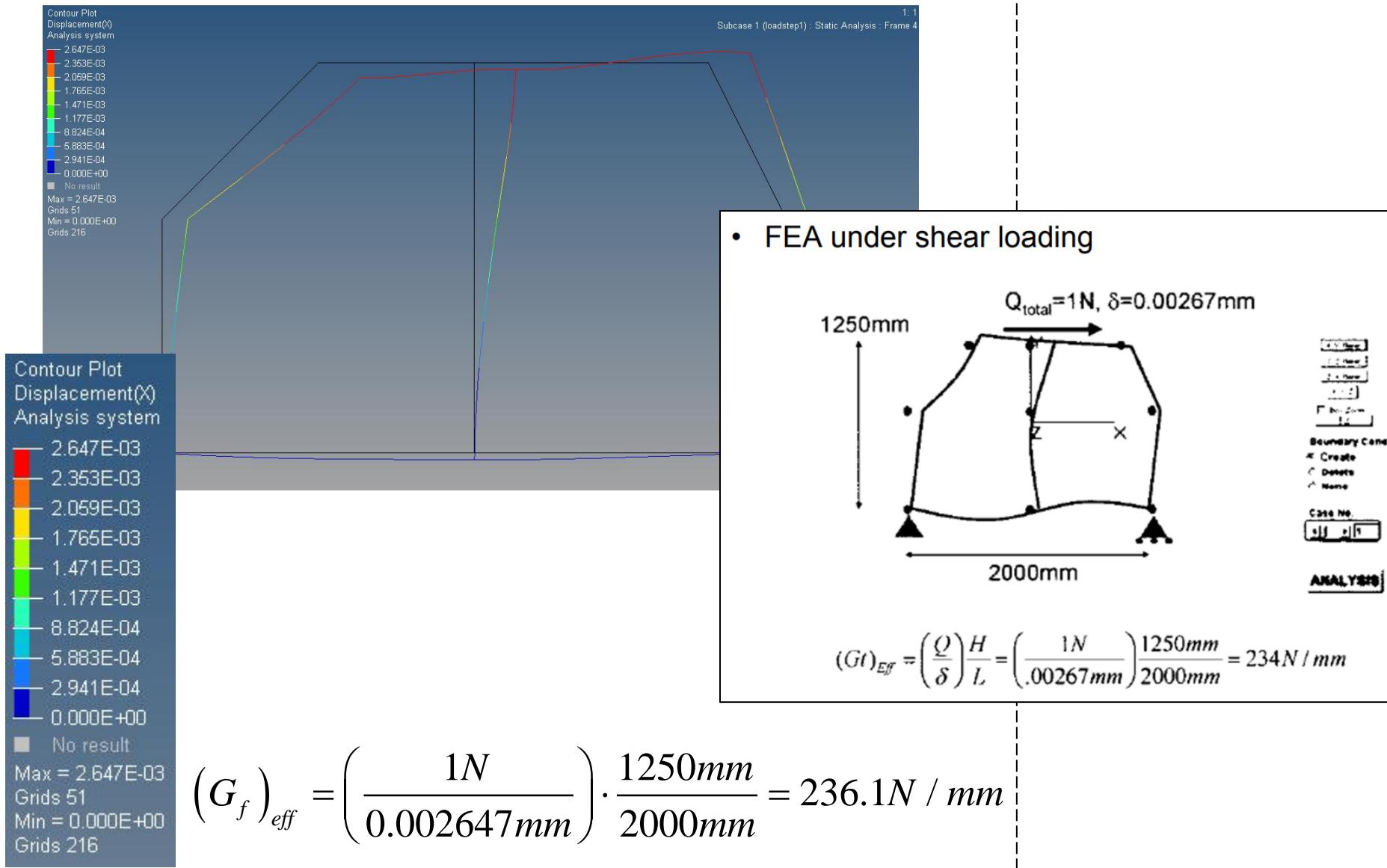


1 Contour 클릭  
Displacement, X  
Apply

2 Deformed 클릭  
Value > 5e4  
Apply

3 Animation Control 클릭  
Max Frame Rate > 1  
Start animation

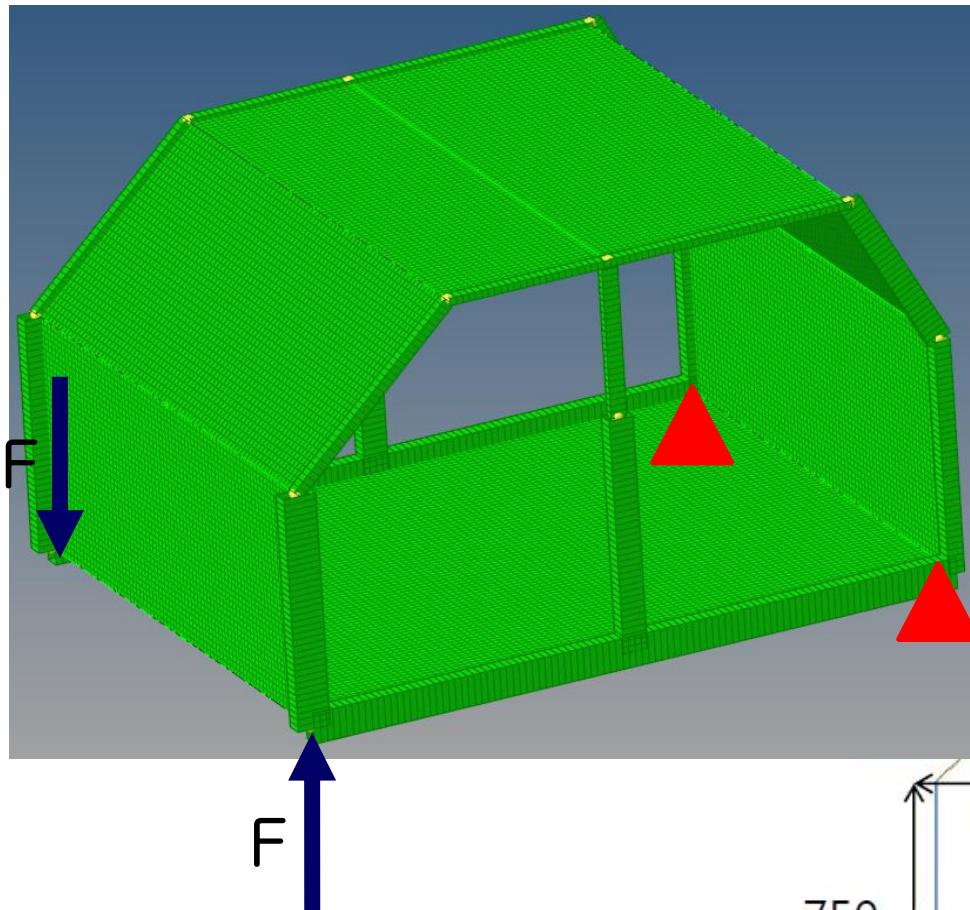
# 후처리



# TORSIONAL STIFFNESS (SHELL + BEAM ELEMENTS)

# 예제: TORSIONAL STIFFNESS (1)

다음 주어진 기하형상의 비틀림 강성을 구하시오. (프레임은 앞 예제의 모델 이용)

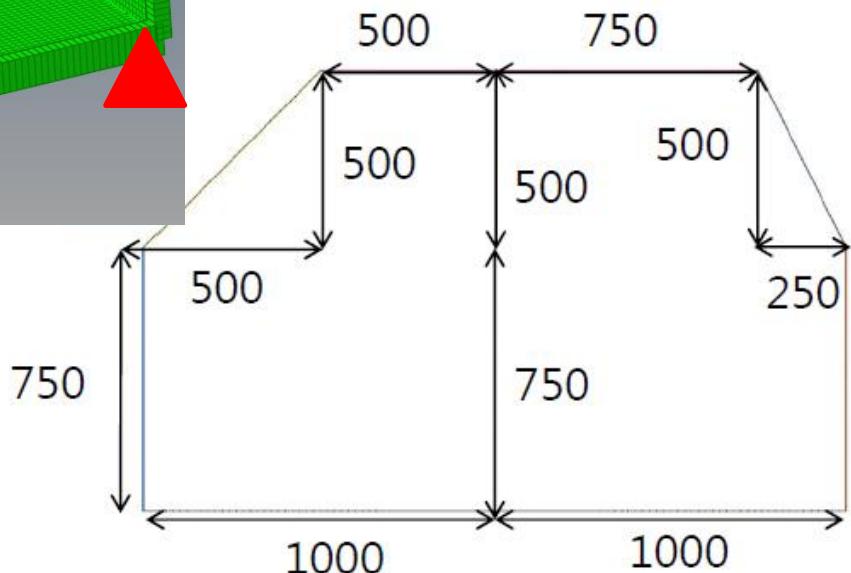


## Material

- $E = 204.8 \text{ GPa}$
- $\nu = 0.28$
- $G = 80 \text{ GPa}$

## Force

- $T = 7730000 \text{ Nmm}$
- $F = 7730000/1560$   
 $= 4955.13 \text{ N}$



# 예제: TORSIONAL STIFFNESS (2)

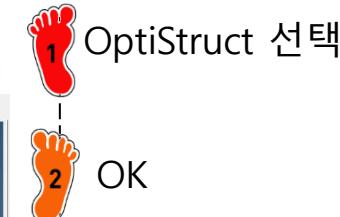
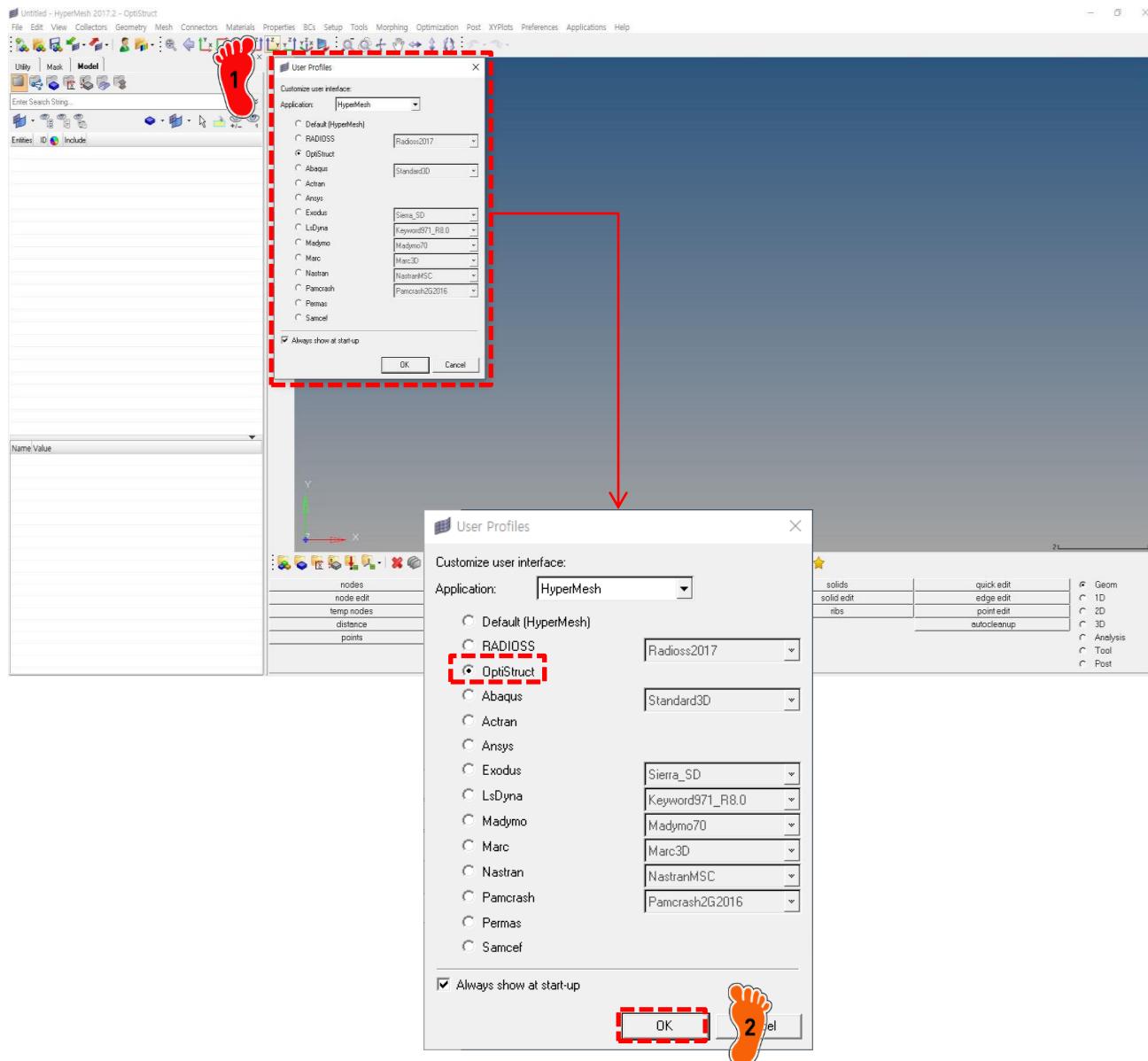
다음 주어진 기하형상의 비틀림 강성을 구하시오

$$T = 7,730,000 \text{ Nmm}, q = 2678\text{N} / 1250\text{mm} = 2.1414\text{N/mm}$$

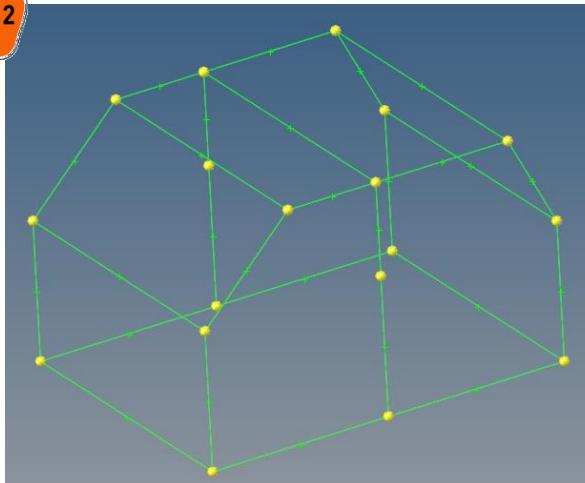
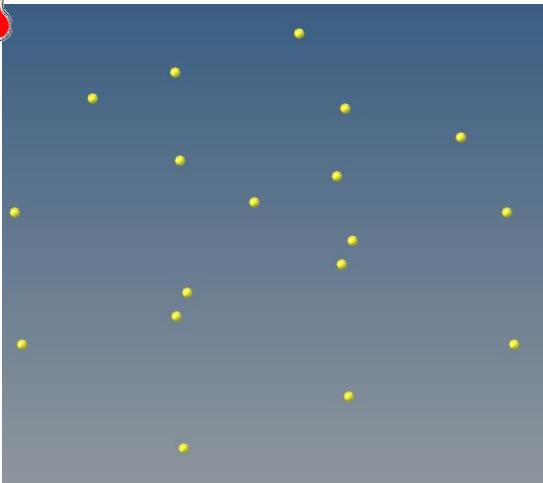
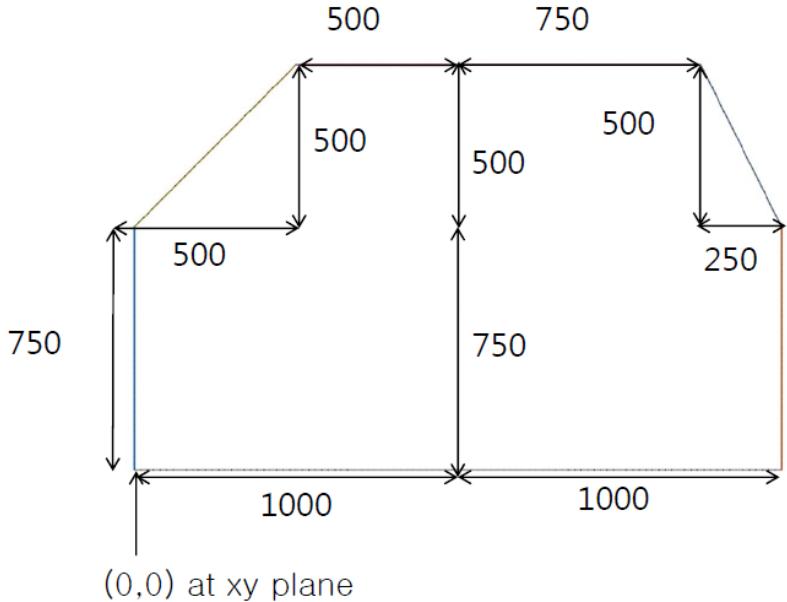
Panel	Area of panel (mm <sup>2</sup> )	Effective shear rigidity (Gt) <sub>EFF</sub> (N/mm)	Area of surface / (Gt) <sub>EFF</sub> (mm <sup>3</sup> /N)
dash	1170000	80000	14.6
windshield	1103087	80000	13.8
roof	1950000	80000	24.4
back light	872067	80000	10.9
seat back	1170000	80000	14.6
floor	3120000	80000	29.0
side frame-left	2312500	234	9882.5
side frame-right	2312500	234	9882.5

$$K = \frac{1}{\left(\frac{q}{T}\right)^2 \sum_{\text{ALL SURFACE}} \left[ \frac{\text{area of surface}}{(Gt)_{\text{EFF}}} \right]} = 6.55 \times 10^8 \text{ Nmm/rad}$$

# 기하형상 생성 (1)



# 기하형상 생성 (2)



1 주어진 기하형상 생성

점 좌표

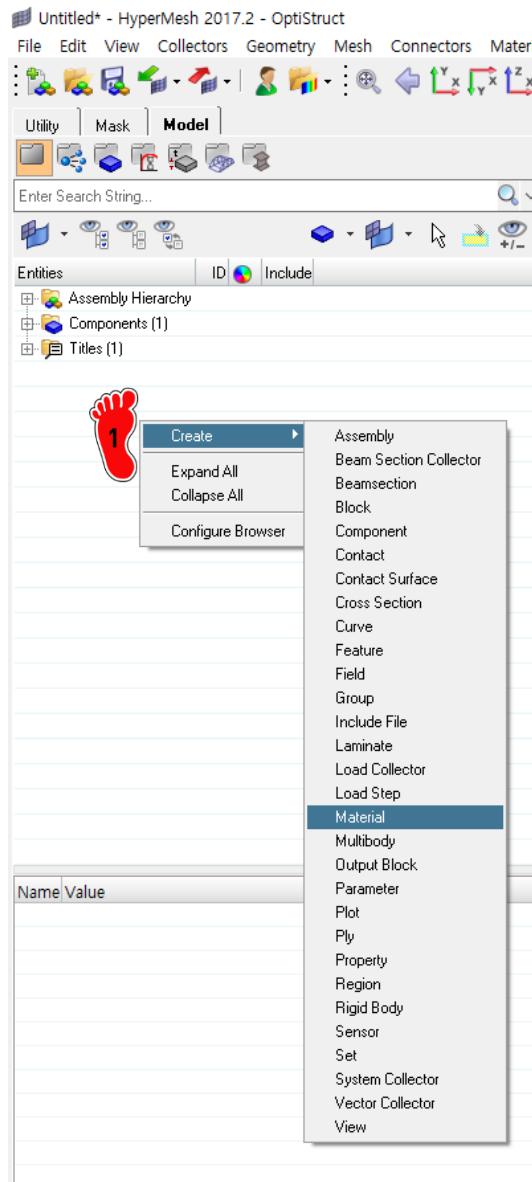
(0,0,0)  
(0,750,0)  
(500,1250,0)  
(1000,0,0)  
(1000,750,0)  
(1000,1250,0)  
(1750,1250,0)  
(2000,0,0)  
(2000,750,0)

반대편 sideframe을 모델링  
하기 위해,  
Z축방향으로 1560mm 평행  
이동된 점 9개 추가로 생성



2 생성한 점들을 연결하여 그  
림과 같이 선 생성

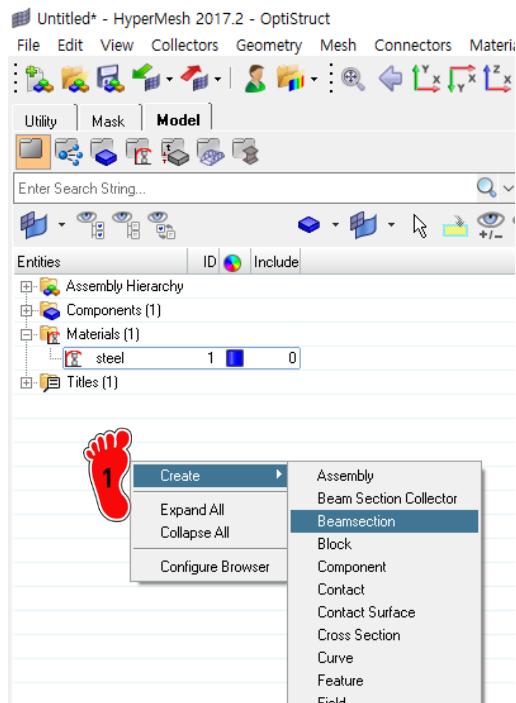
# 재료 물성 및 특성 입력 (1)



Name	Value
Solver Keyword	MAT1
Name	steel
ID	1
Color	green
Include	[Master Model]
Defined	<input checked="" type="checkbox"/>
Card Image	MAT1
User Comments	Do Not Export
E	204800.0
G	
NU	0.28

- 1 우클릭, Create > Material
- 2 Name > steel  
탄성계수(E)  
> 204.8Gpa (204800 N/mm<sup>2</sup>)  
푸아송비(NU) > 0.28  
재료 생성

# 재료 물성 및 특성 입력 (2)

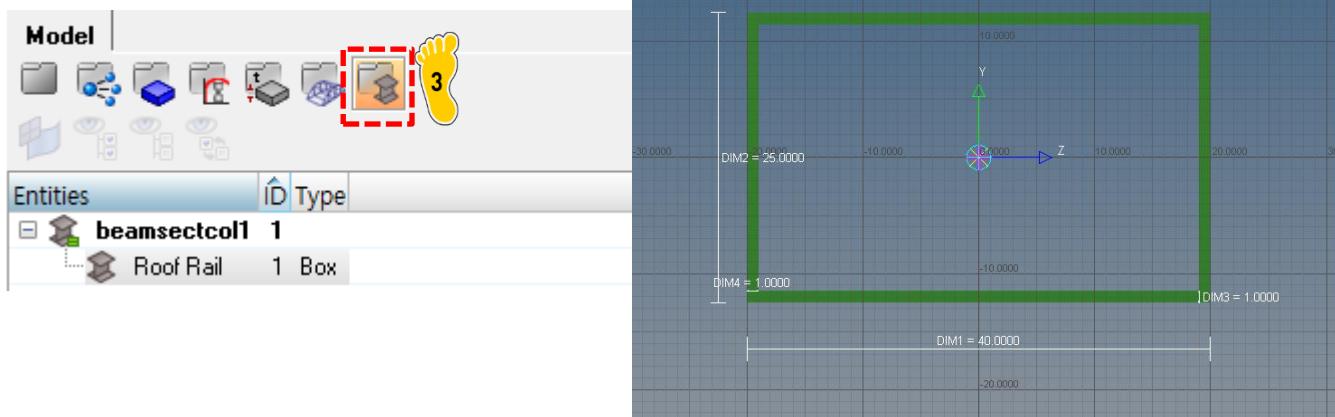


Name	Value
Name	Roof Rail
ID	1
Include	[Master Model]
Collector	(1) beamsectcol1
Config	Standard
2 Section Type	BOX
<b>Parameter Definitions</b>	
Dimension DIM1	40.0
Dimension DIM2	25.0
Thickness DIM3	1.0
Thickness DIM4	1.0

1 우클릭,  
Create > Beamsection

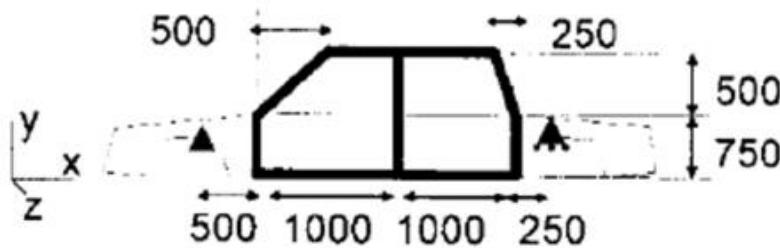
2 Section Type > BOX,  
단면형상 입력

3 Hyperbeam view에서 단면  
형상 확인 가능



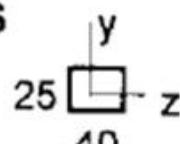
# 재료 물성 및 특성 입력 (3)

**Sideframe Dimensions  
(all in mm)**

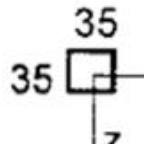


## SECTIONS

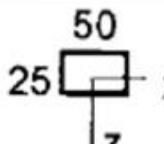
(t=1mm)



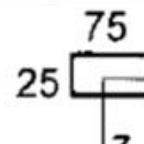
Roof Rail



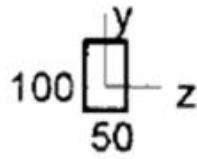
A Pillar



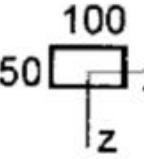
B Pillar  
above Belt



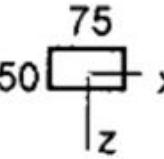
C Pillar  
above Belt



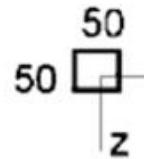
Rocker



Hinge  
Pillar



B Pillar  
Below Belt



C Pillar  
Below Belt



1 예제에서 주어진 단면형상 8개를 각각 생성



2 Dimension DIM1에 Z방향 길이 입력

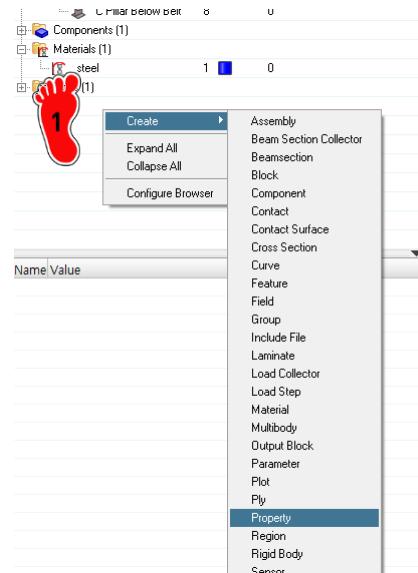
Assembly Hierarchy		
Beam Section Collectors (1)		
beamsectcoll	1	0
Roof Rail	1	0
A Pillar	2	0
B Pillar above Belt	3	0
C Pillar above Belt	4	0
Rocker	5	0
Hinge Pillar	6	0
B Pillar Below Belt	7	0
C Pillar Below Belt	8	0

Name	Value
Name	Roof Rail
ID	1
Include	[Master Model]
Collector	(1) beamsectcoll
Config	Standard
Section Type	BOX
Parameter Definitions	
Dimension DIM1	40.0
Dimension DIM2	25.0
Thickness DIM3	1.0
Thickness DIM4	1.0



2 Dimension DIM1에 Z방향 길이 입력

# 재료 물성 및 특성 입력 (4)



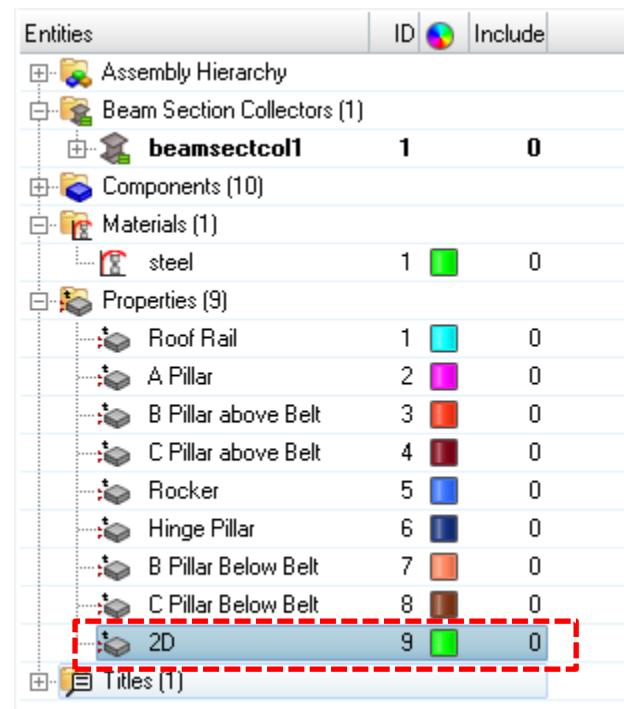
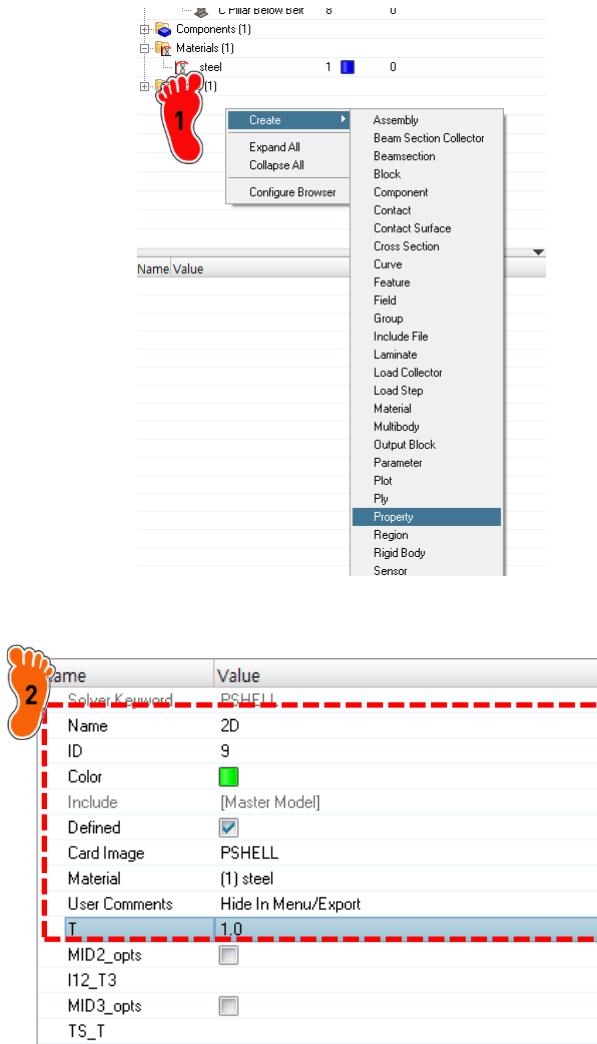
Entities	ID	Color	Include
<b>Beam Section Collectors (1)</b>			
beamsectcol1	1	0	
Roof Rail	1	0	
A Pillar	2	0	
B Pillar above Belt	3	0	
C Pillar above Belt	4	0	
Rocker	5	0	
Hinge Pillar	6	0	
B Pillar Below Belt	7	0	
C Pillar Below Belt	8	0	
<b>Components (1)</b>			
<b>Materials (1)</b>			
steel	1	0	
<b>Properties (8)</b>			
Roof Rail	1	0	
A Pillar	2	0	
B Pillar above Belt	3	0	
C Pillar above Belt	4	0	
Rocker	5	0	
Hinge Pillar	6	0	
B Pillar Below Belt	7	0	
C Pillar Below Belt	8	0	

1 우클릭,  
Create > Property

2 Property 8개 각각 생성, 단면 형상과 각각 연결  
Card Image > PBEAM  
Material > steel  
Beam Section > 단면형상  
각각 선택  
Name > 단면 형상과 동일  
하게

Name	Value
Solver Keyword	PBEAM
Name	Roof Rail
ID	1
Color	00FFFF
Include	[Master Model]
Defined	<input checked="" type="checkbox"/>
Card Image	PBEAM
Material	(1) steel
User Comments	Hide In Menu/Export
Beam Section	(1) Roof Rail
PBEAM_CARD3 =	0

# 재료 물성 및 특성 입력 (5)

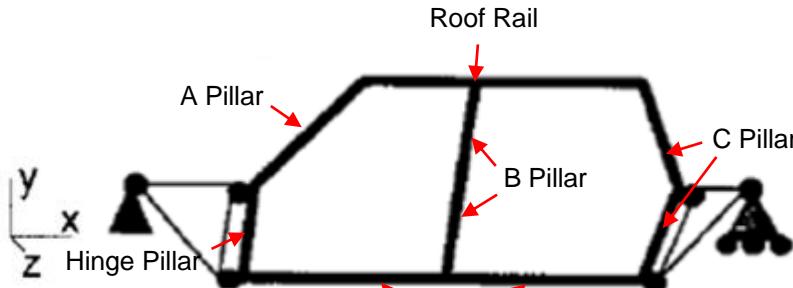


1 우클릭,  
Create > Property

2 Card Image > PSHELL  
Material > steel  
T > 1mm  
Name > 2D

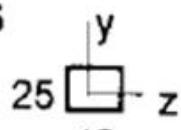
# 요소망 생성 (1)

**Sideframe Dimensions**  
(all in mm)

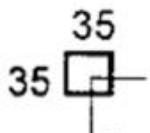


## SECTIONS

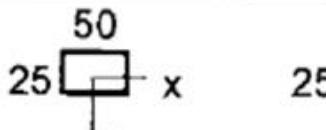
(t=1mm)



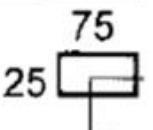
Roof Rail



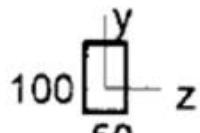
A Pillar



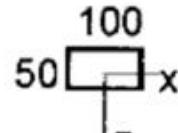
B Pillar  
above Belt



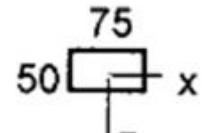
C Pillar  
above Belt



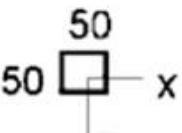
Rocker



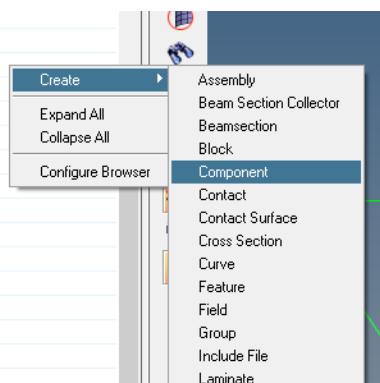
Hinge  
Pillar



B Pillar  
Below Belt



C Pillar  
Below Belt



Name	Value
Name	Roof Rail
ID	2
Color	[Blue]
Include	[Master Model]
Property	(1) Roof Rail
Material	(1) steel

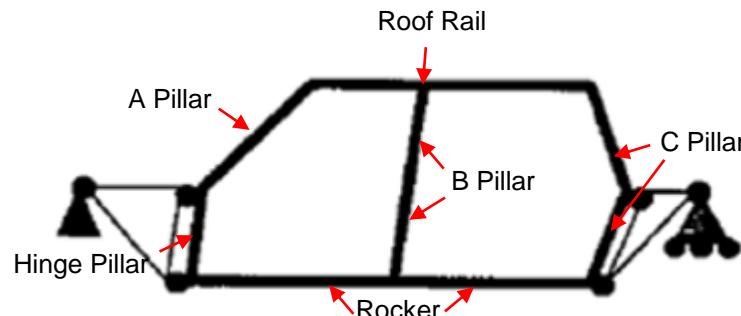
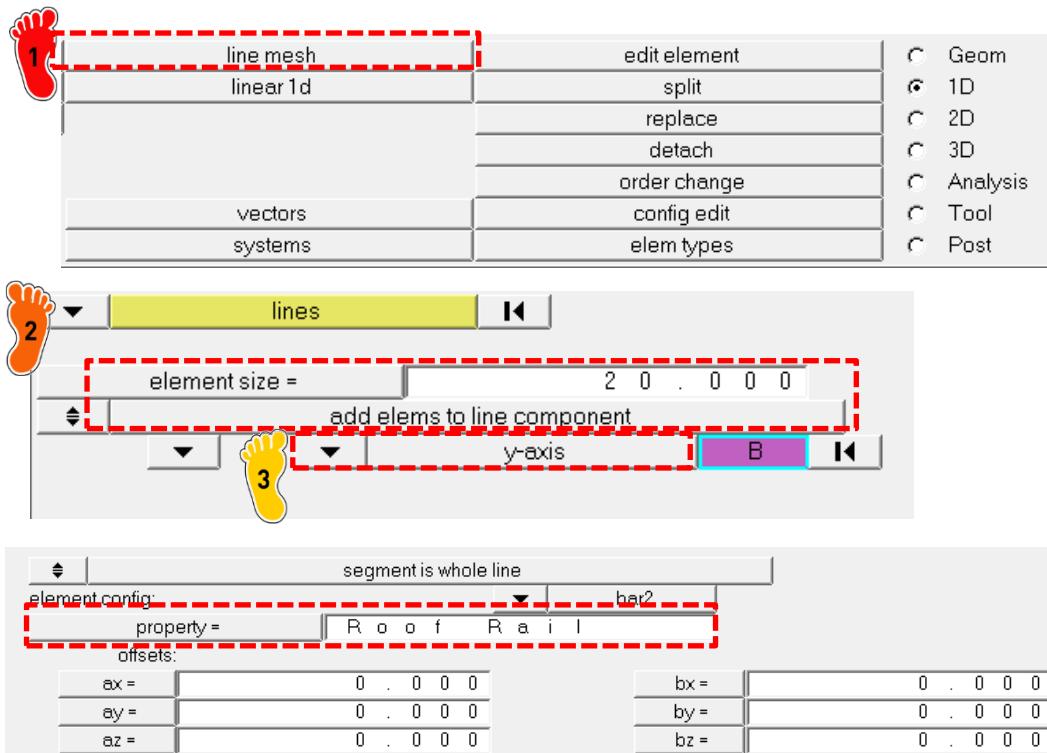


1 우클릭,  
Create > Component



2 Name, Property  
>요소망 생성할 단면형상의  
이름과 동일하게

# 요소망 생성 (2)



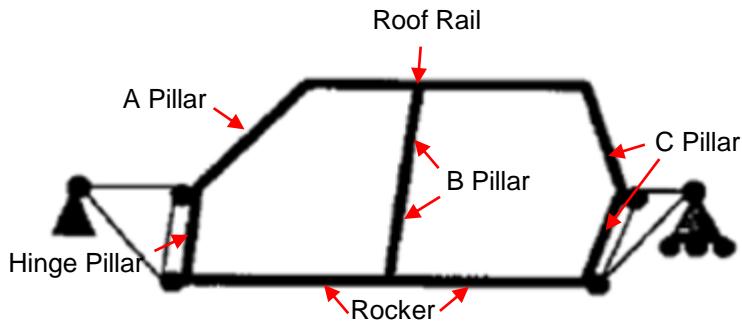
**1** 1D > line mesh 클릭

**2** 요소망 생성  
크기 > 20  
Add elems to current  
component  
Property > 단면형상 이름  
과 동일하게

**3** 요소망 생성시 단면 형상이  
원하는 좌표축에 놓이도록  
주의(x축과 평행한 빔은 y-  
aixs로 선택, y축과 평행한  
빔은 x-aixs로 선택)

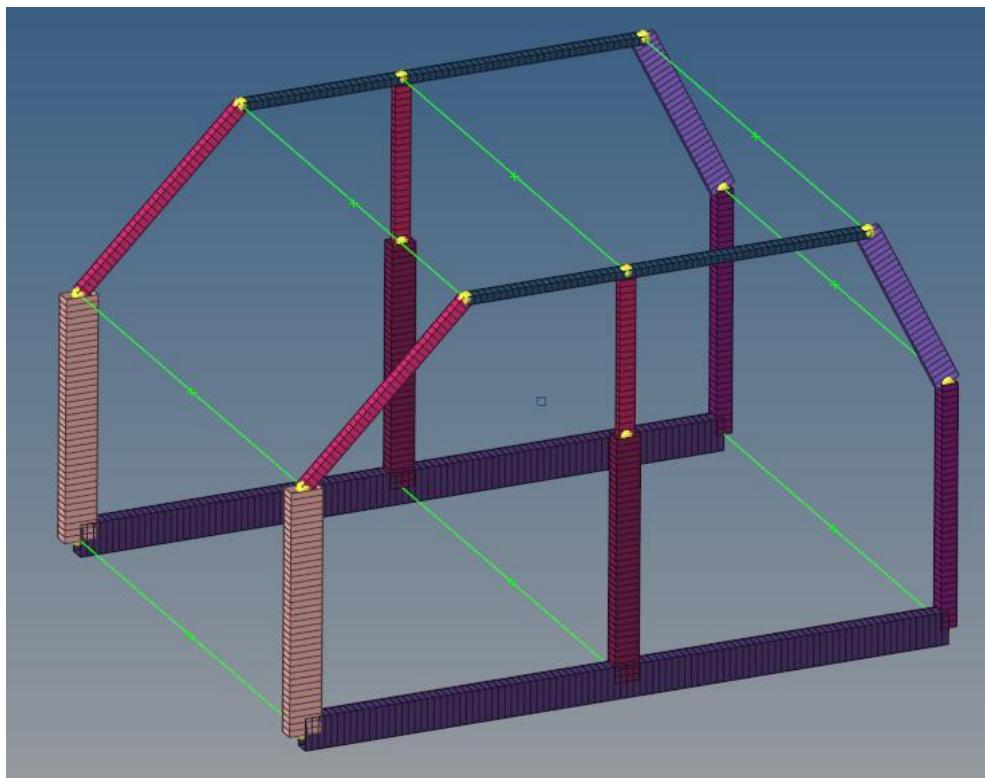
**4** Mesh,  
Return

# 요소망 생성 (3)



1 앞의 과정(1,2) 반복해서  
8개 빔 요소망 생성

그림과 비슷한 형상이  
나와야 함



# 요소망 생성 (4)

**Components (9)**

Roof Rail	1	0
A Pillar	2	0
B Pillar above Belt	3	0
C Pillar above Belt	4	0
Rocker	5	0
Hinge Pillar	6	0
B Pillar Below Belt	7	0
C Pillar Below Belt	8	0
2D	9	0

**Materials (1)**

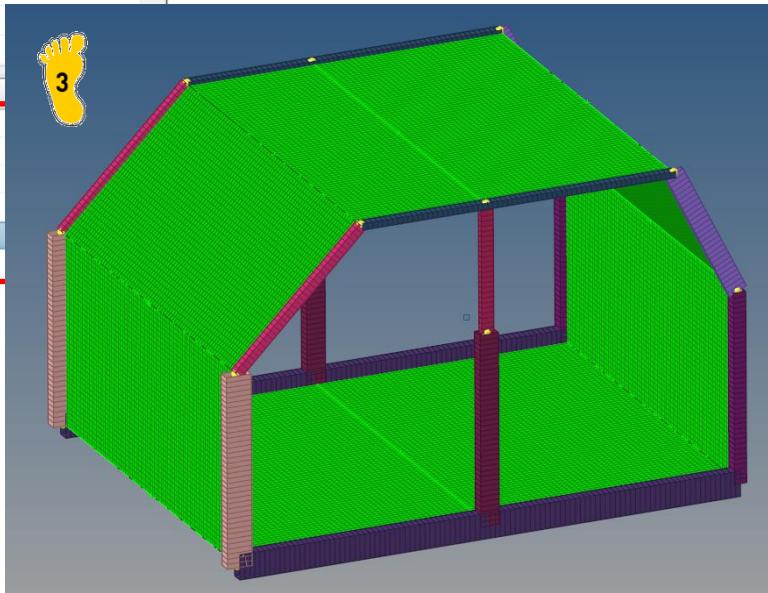
steel	1	0
-------	---	---

**Properties (9)**

Roof Rail	1	0
A Pillar	2	0
B Pillar above Belt	3	0
C Pillar above Belt	4	0
Rocker	5	0
Hinge Pillar	6	0
B Pillar Below Belt	7	0

**2D**

Name	Value
Name	2D
ID	9
Color	green
Include	[Master Model]
Property	(9) 2D
Material	(1) steel



1 우클릭,  
Create > Component

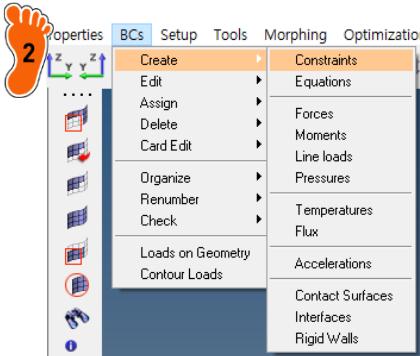
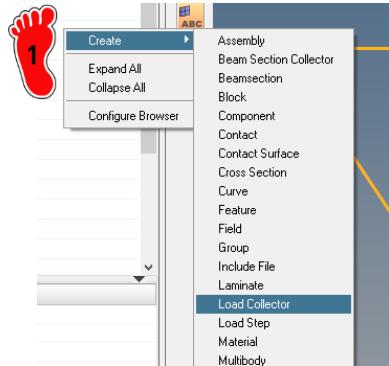
2 Name > 2D  
Property > 2D  
Material > steel

3 2D > planes  
20 mm 인 크기로 평면요소  
생성

\* Tool -> edges ->  
tolerance -> equivalence  
(모서리 병합)

\* Geom -> temp nodes ->  
clear all (Nodes 제거)

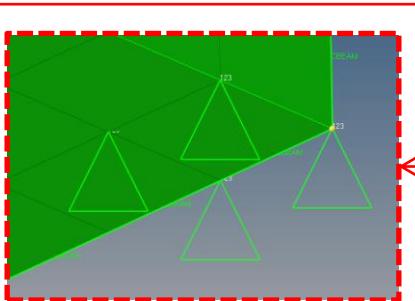
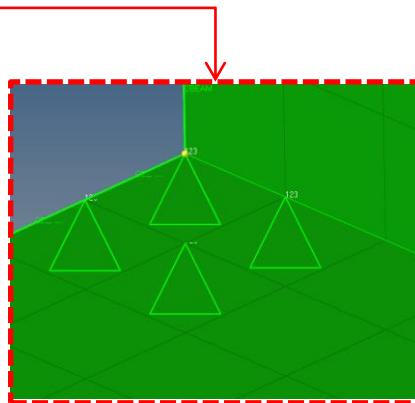
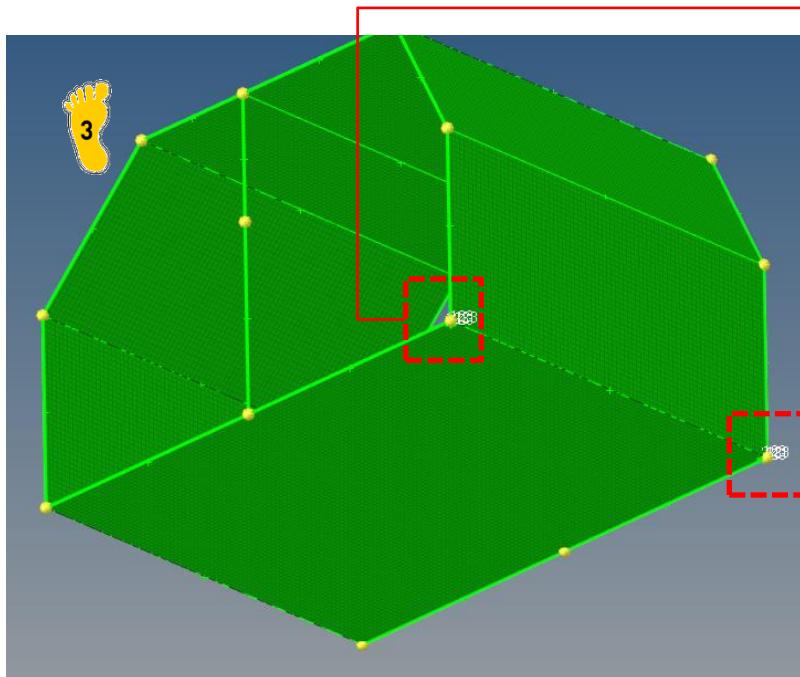
# 구속조건 및 하중조건 설정 (1)



1 Create > Load Collector  
Name > spc

2 BCs > Create  
> Constraints

3 뒤쪽 양 끝 요소의 절점 4개  
를 핀 구속조건으로 구속



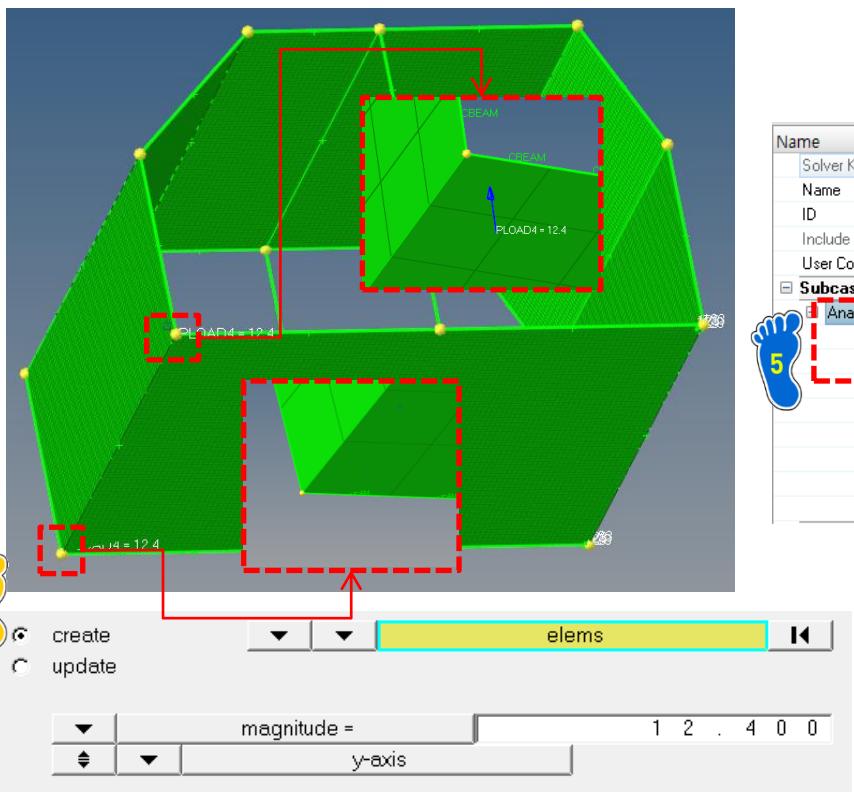
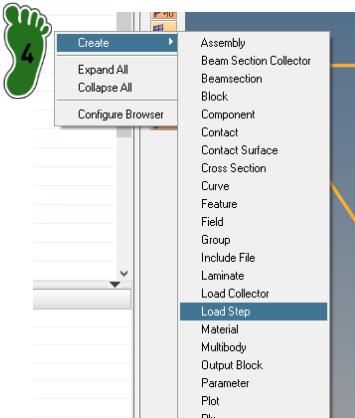
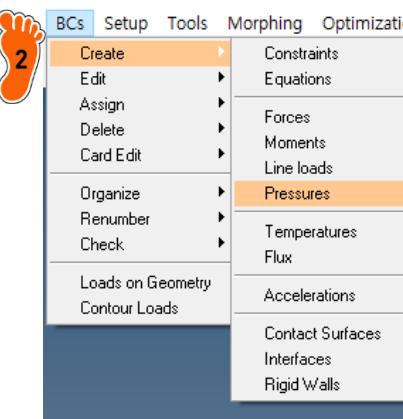
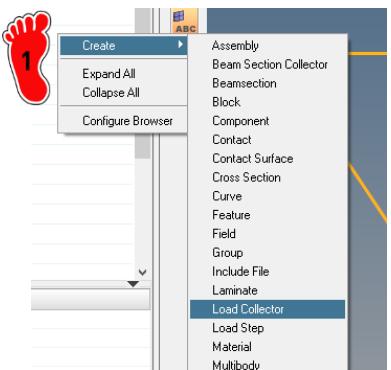
<input checked="" type="checkbox"/> dof1	=	0 . 0 0 0
<input checked="" type="checkbox"/> dof2	=	0 . 0 0 0
<input checked="" type="checkbox"/> dof3	=	0 . 0 0 0
<input type="checkbox"/> dof4	=	0 . 0 0 0
<input type="checkbox"/> dof5	=	0 . 0 0 0
<input type="checkbox"/> dof6	=	0 . 0 0 0

load types = S P C

create  
create/edit  
reject  
review

return

# 구속조건 및 하중조건 설정 (2)



Name	Value
Solver Keyword	SUBCASE
Name	loadstep1
ID	1
Include	[Master Model]
User Comments	Hide In Menu/Export
Subcase Definition	
Analysis type	Linear Static
SPC	(1) SPC
LOAD	(2) Pressures
SUPPORT	<Unspecified>
PRETENSION	<Unspecified>
MPC	<Unspecified>
DEFORM	<Unspecified>
STATSUB (PRELOAD)	<Unspecified>
STATSUB (PRETENS)	<Unspecified>

5 Analysis type > Linear Static  
SPC > spc  
LOAD > Pressures

1 Create > Load Collector  
Name > Pressures

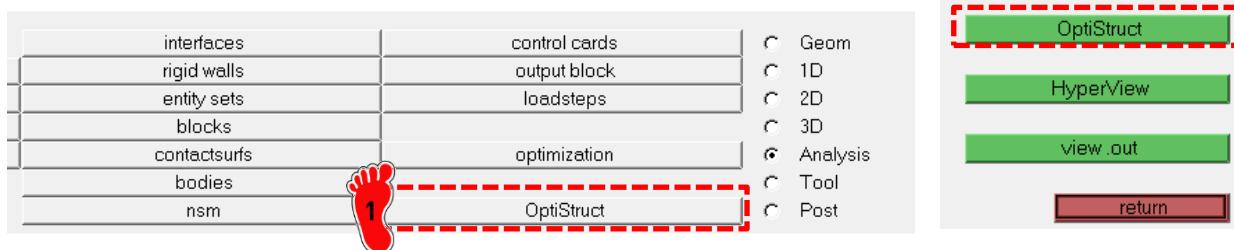
2 BCs > Create > Pressures

3 하중/면적  
=(4955/400)=12.4 N/mm<sup>2</sup>  
인 압력하중으로 비틀림 하중을 적용  
(양쪽 부호 다르게)

4 Create > Load Step

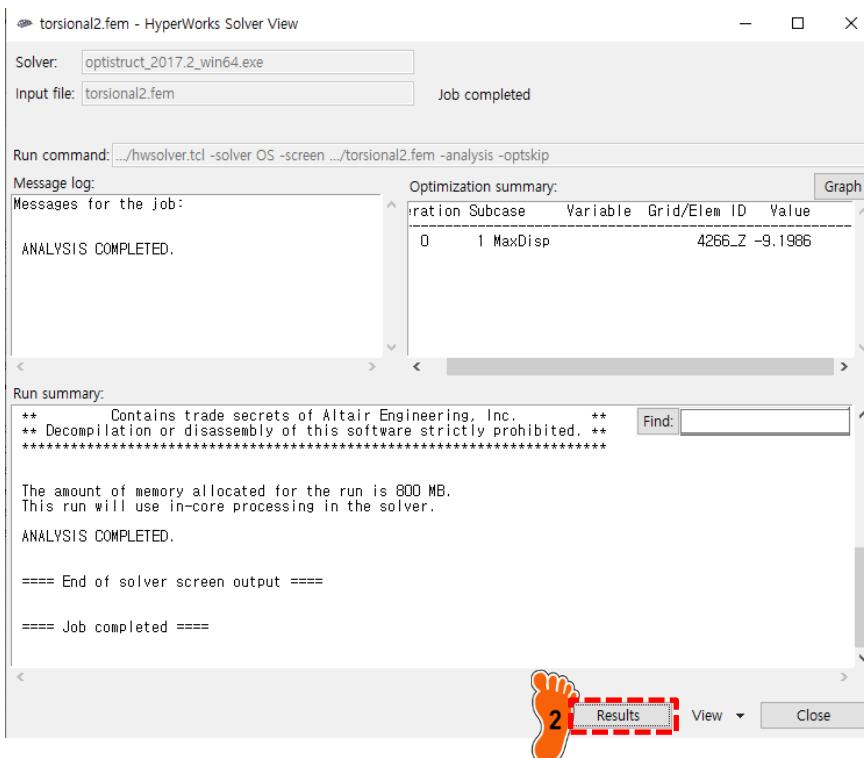
5 Analysis type > Linear Static  
SPC > spc  
LOAD > Pressures

# 해석 케이스 정의 및 해석 실행

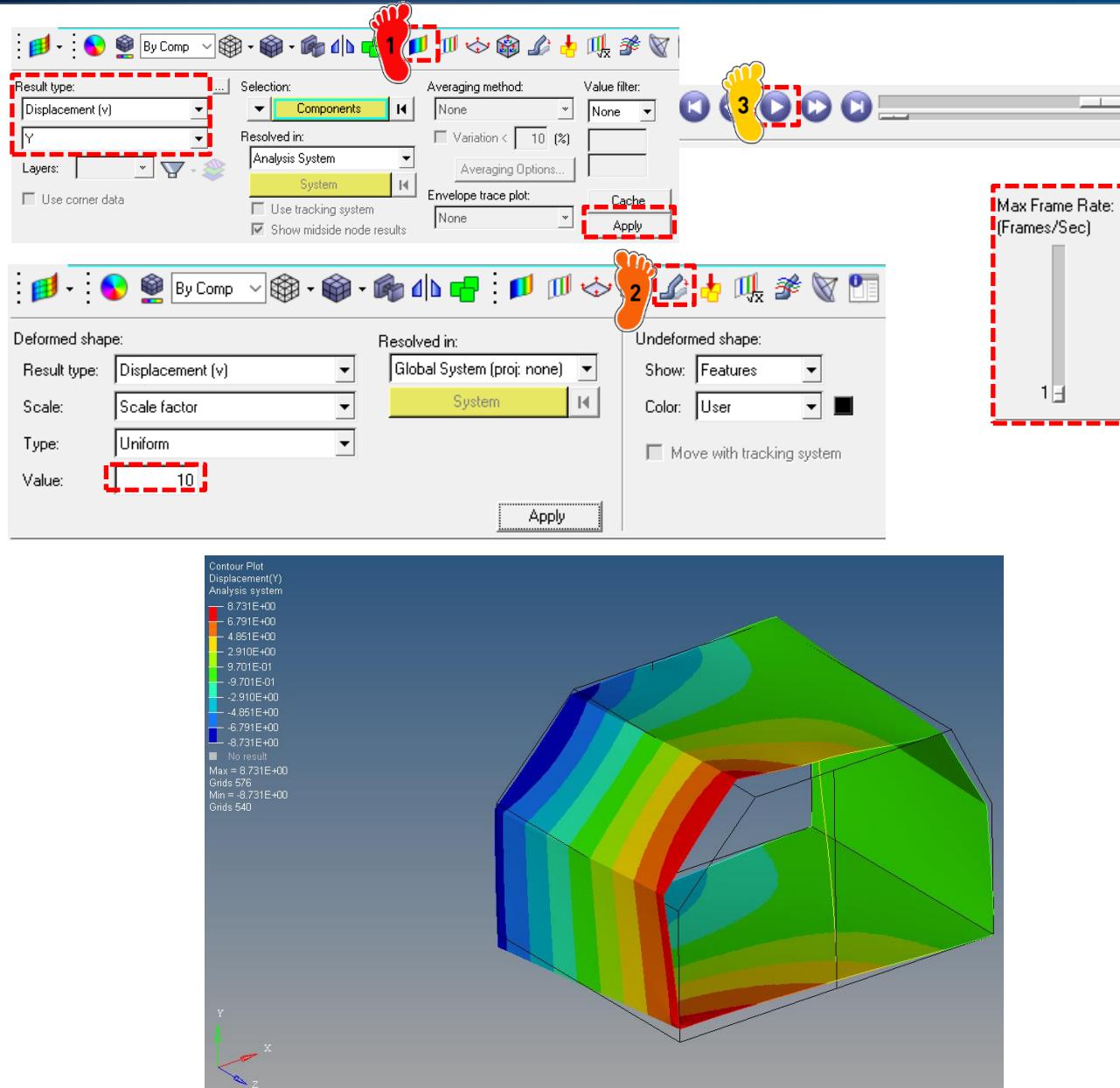


1 Analysis > OptiStruct 클릭  
OptiStruct

2 Results 클릭



# 후처리

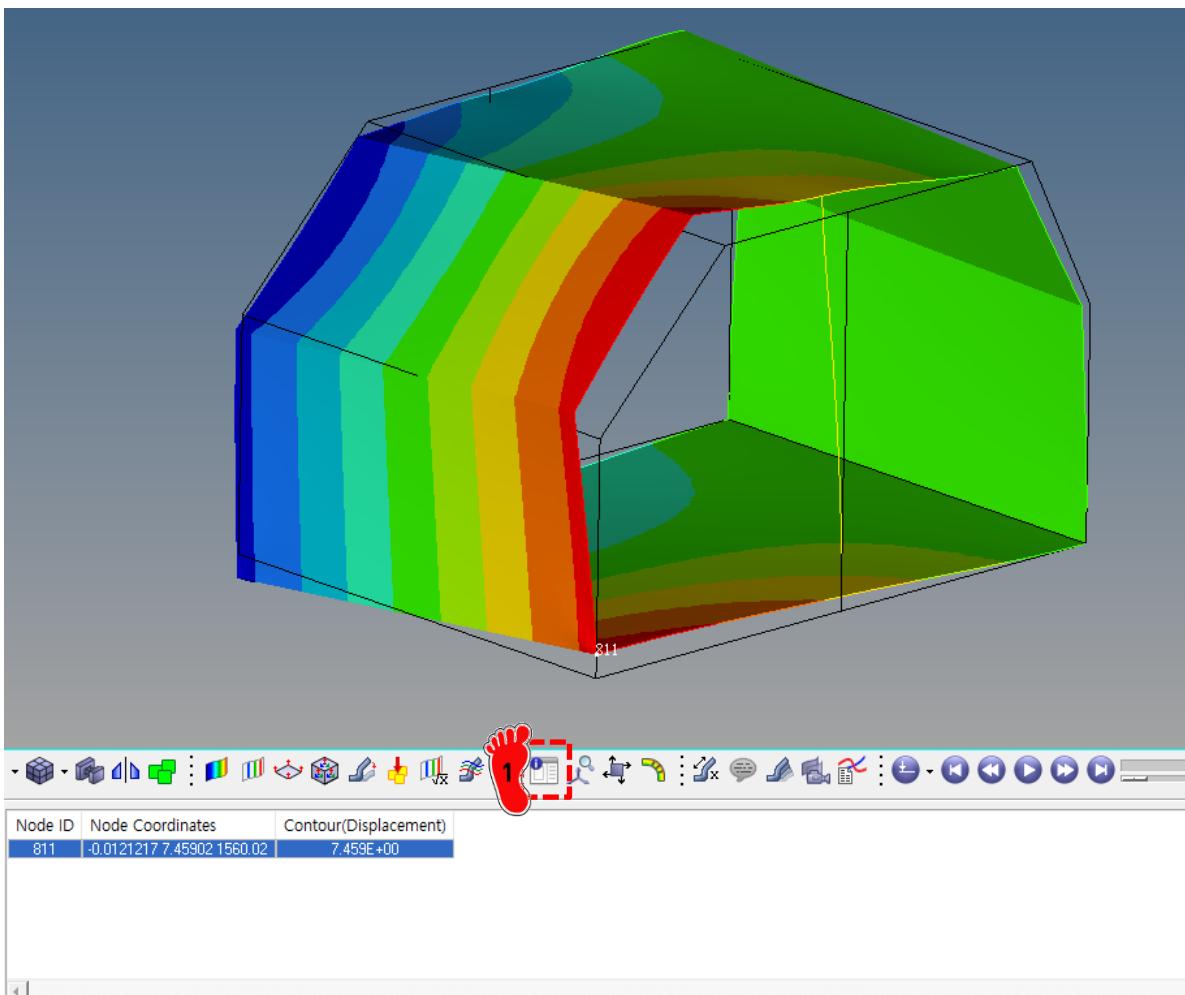


1 Contour 클릭  
Displacement, Y  
Apply

2 Deformed 클릭  
Value > 10  
Apply

3 Animation Control 클릭  
Max Frame Rate > 1  
Start animation

# 후처리



1 Query 클릭

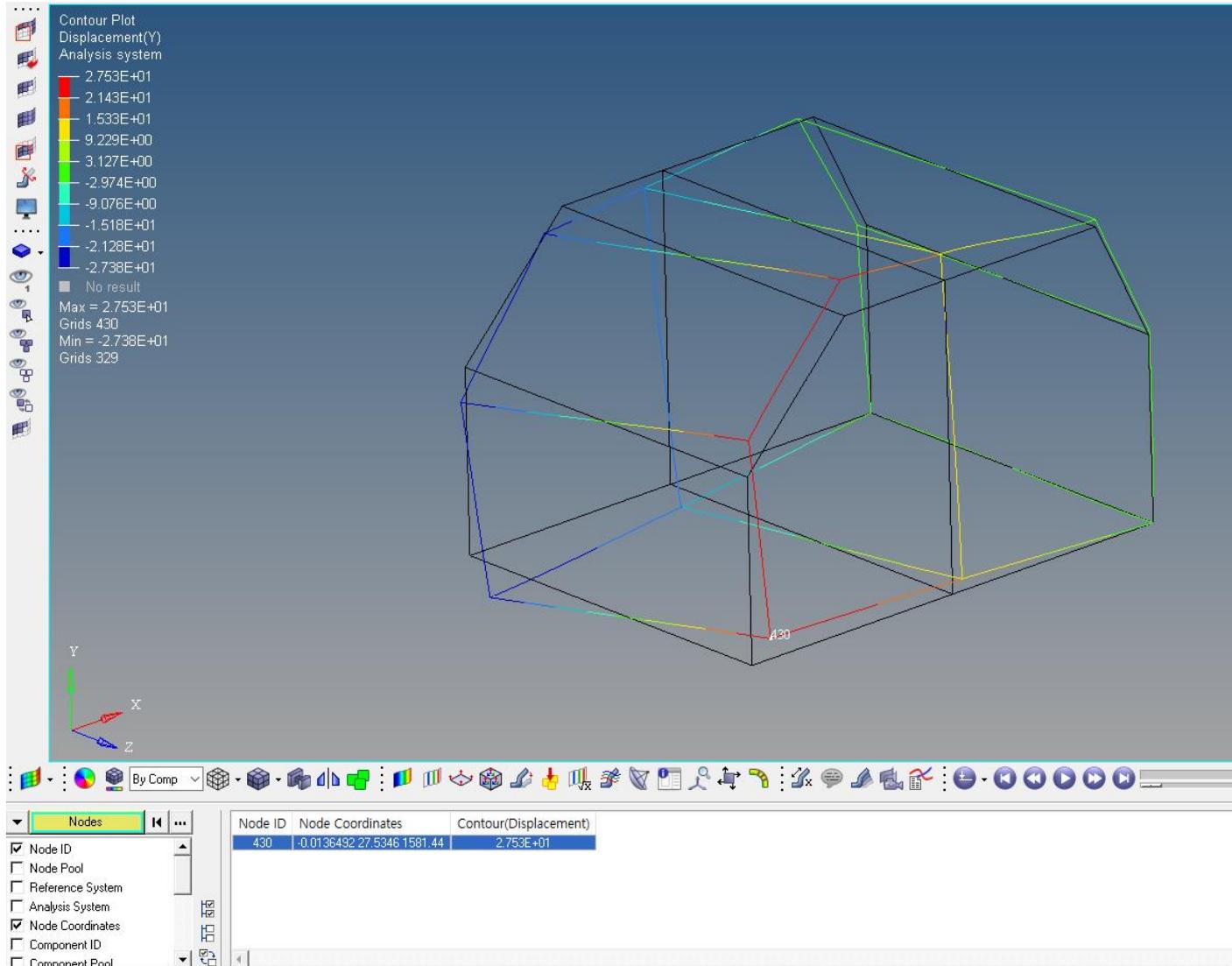
2 앞쪽 끝 노드 클릭

3

$$K = \frac{T}{\theta} = \frac{Fw}{(2\delta/w)} \\ = \frac{7730000}{(2 \times 7.459/1560)} \\ = 8.08e8 \text{ Nmm/rad}$$

(이론:  $6.55e8 \text{ Nmm/rad}$ )

# 숙제



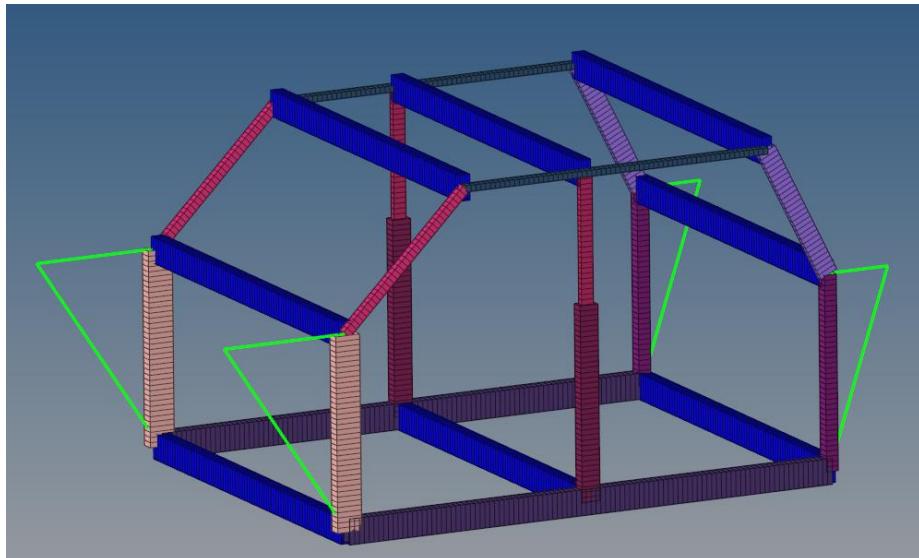
1차원 Beam으로 모델링 후 비틀림 강성을 구하고 앞선 예제와 비교  
(Side frame 외 보강 빔(z축)의 단면 형상은 rocker로 가정하고 해석 수행)

# ADDITIONAL EXAMPLE #1 (MODAL ANALYSIS)

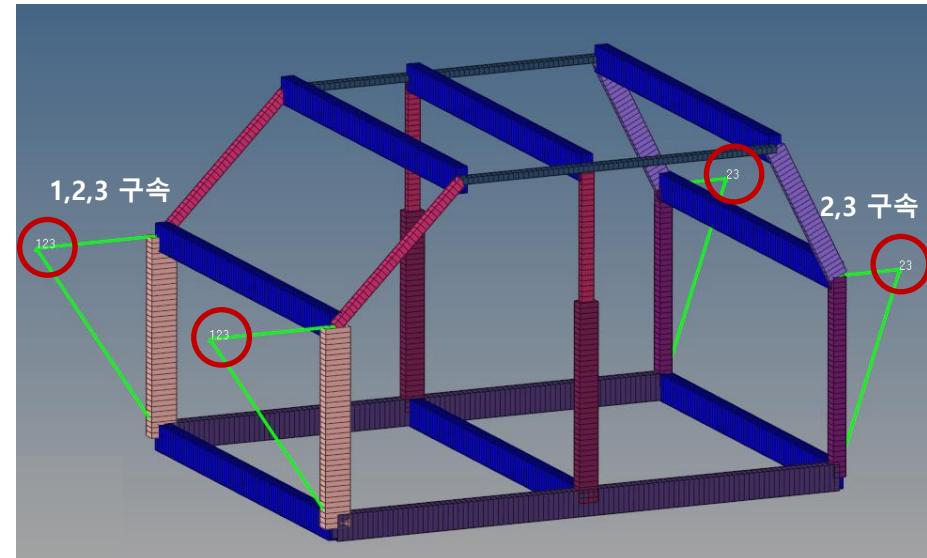
# MODAL ANALYSIS

- 1차원 beam으로 모델링 후 modal analysis 수행 (자유진동 vs. 끝단 구속)

자유진동 가정

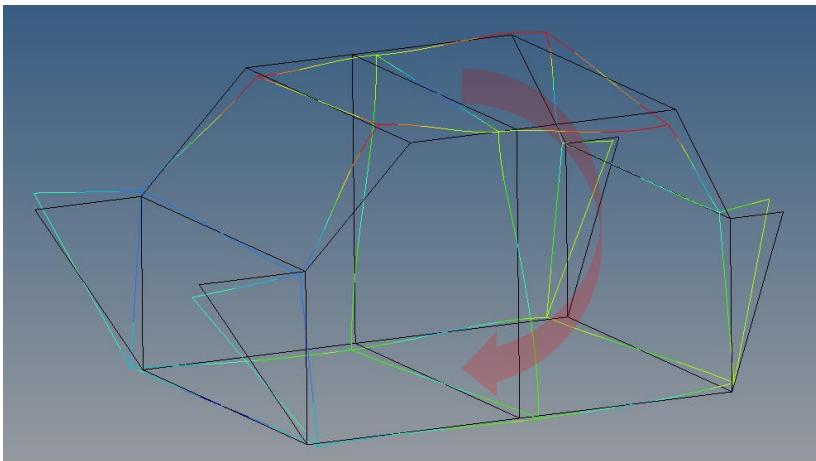


Front & Rear 구속

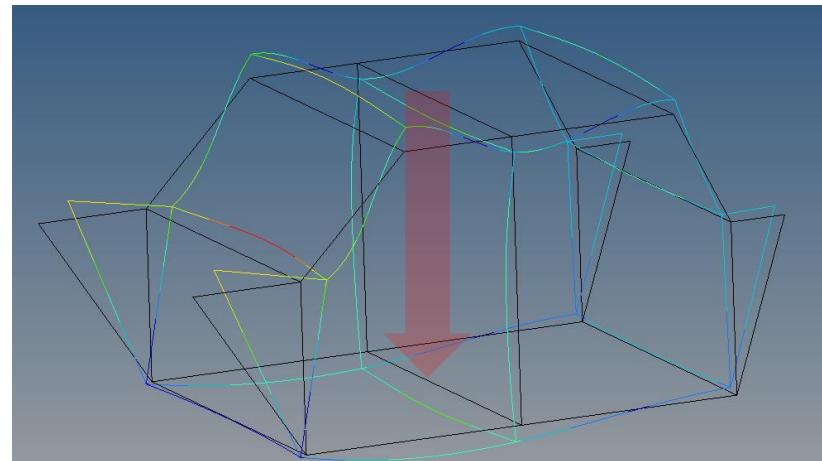


# MODAL ANALYSIS

- 자유진동 가정

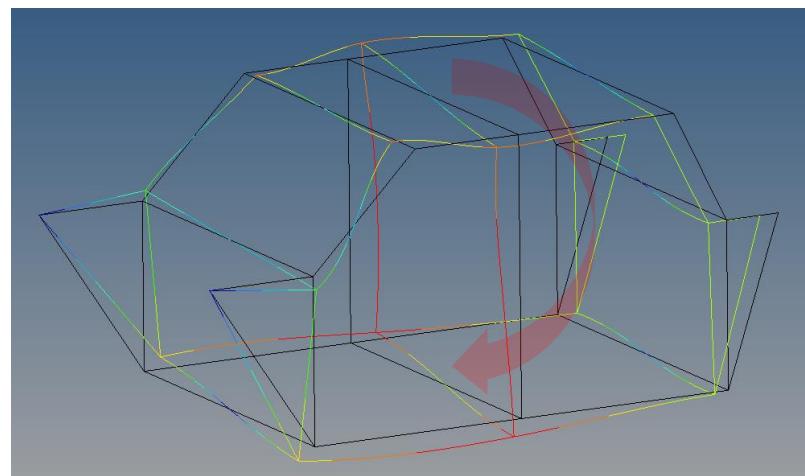


Mode 6(68.89 Hz): Torsion

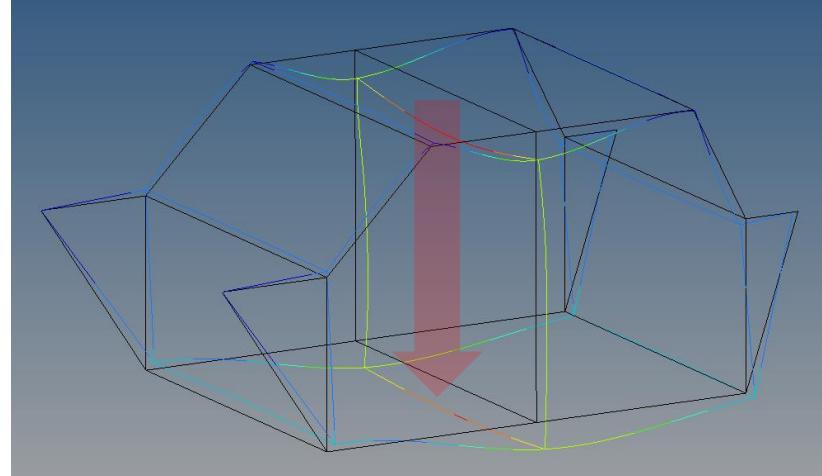


Mode 7(70.04 Hz): Bending

- Front & Rear 구속



Mode 5(54.77 Hz): Torsion

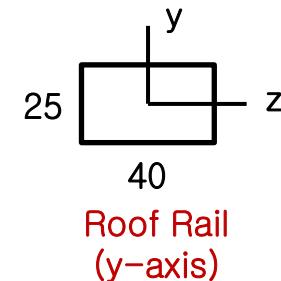
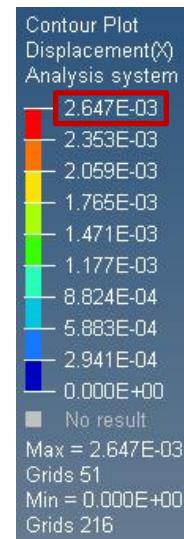
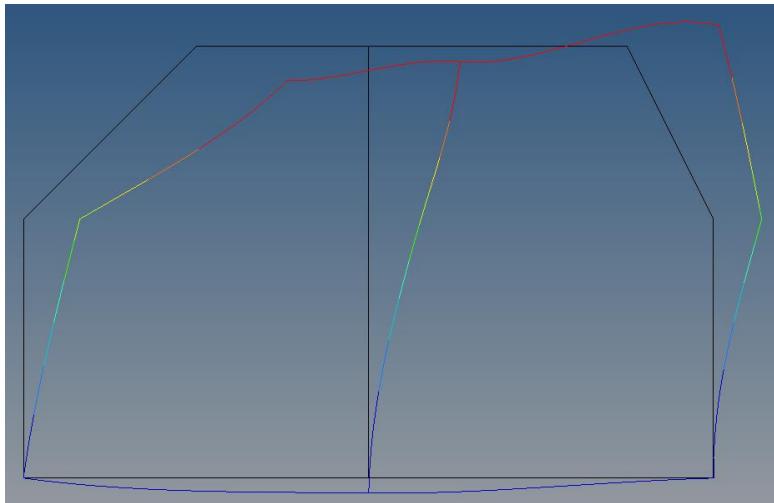


Mode 8(75.92 Hz): Bending

# ADDITIONAL EXAMPLE #2 (EFFECT OF BEAM SECTION)

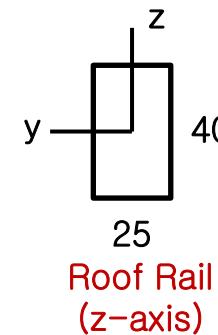
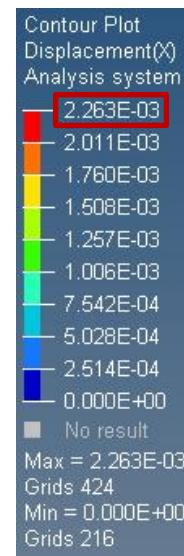
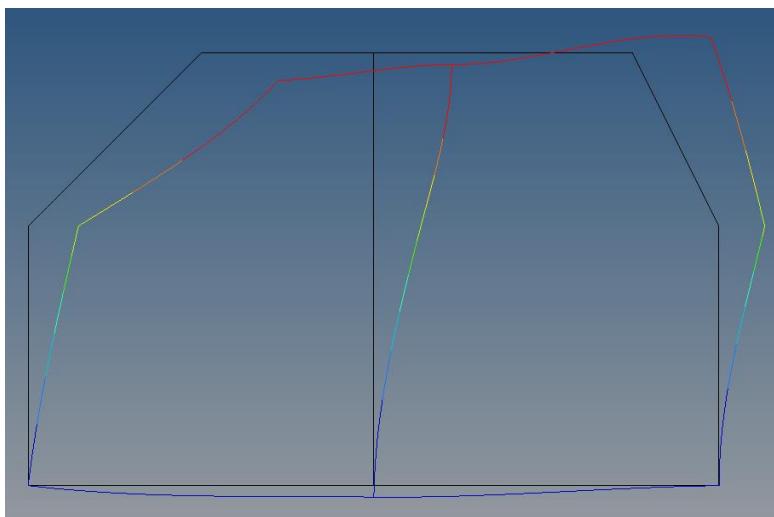
# EFFECT OF BEAM SECTION

- Side frame 모델 비교(effective shear rigidity): Roof rail 변경



$$(G_f)_{eff} = \left( \frac{1N}{0.002647mm} \right) \cdot \frac{1250mm}{2000mm} = 236.1N / mm$$

$$\delta = 0.002647mm$$



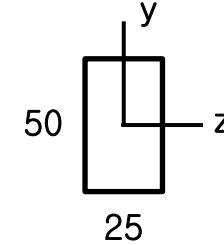
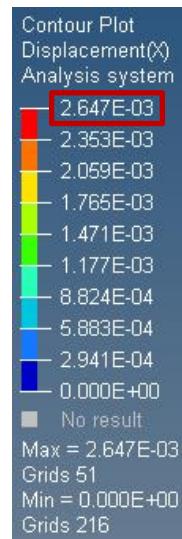
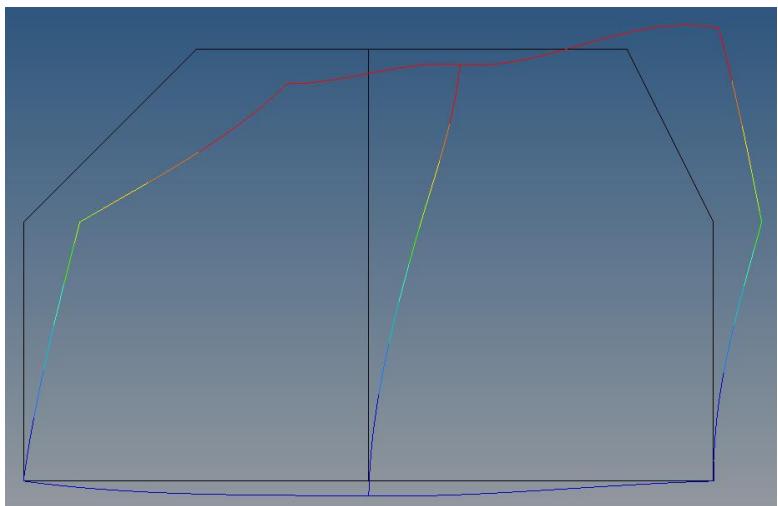
Difference: 16.9%

$$(G_f)_{eff} = \left( \frac{1N}{0.002263mm} \right) \cdot \frac{1250mm}{2000mm} = 276.2N / mm$$

$$\delta = 0.002263mm$$

# EFFECT OF BEAM SECTION

- Side frame 모델 비교(effective shear rigidity): B Pillar above belt 변경

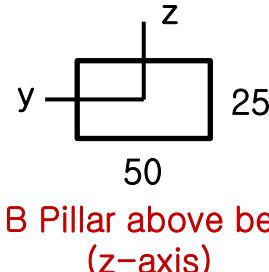
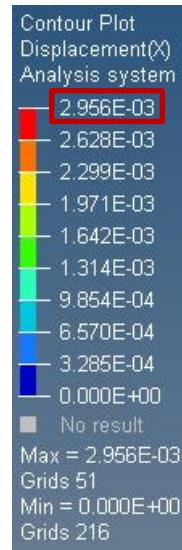
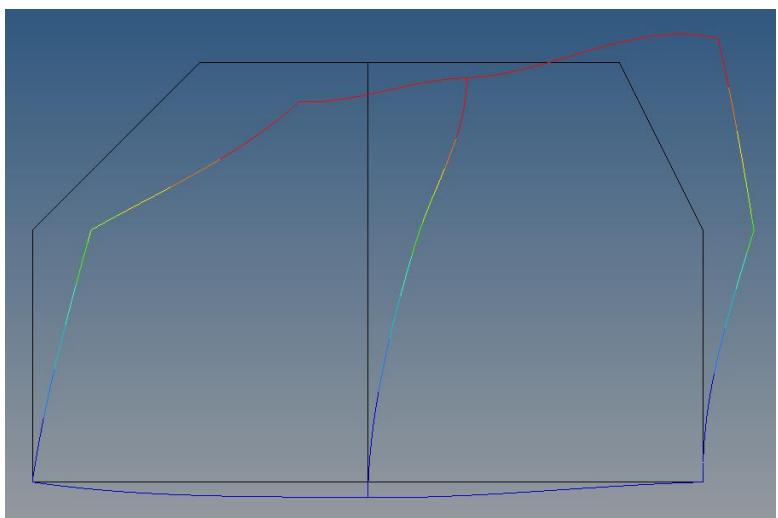


B Pillar above belt  
(y-axis)

Original axis

$$(G_f)_{eff} = \left( \frac{1N}{0.002647mm} \right) \cdot \frac{1250mm}{2000mm} = 236.1N / mm$$

$$\delta = 0.002647mm$$



B Pillar above belt  
(z-axis)

Difference: 10.4%

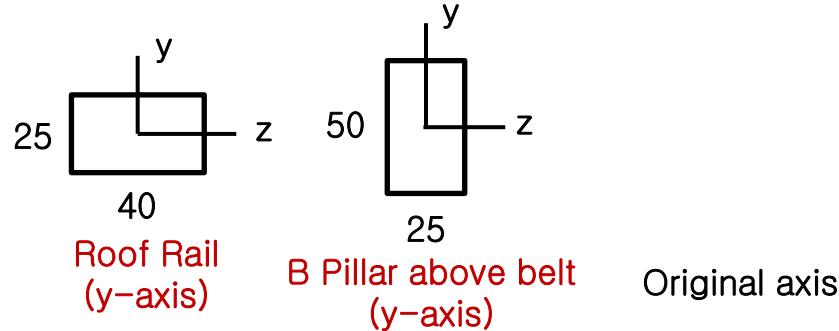
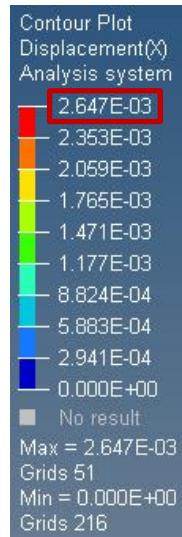
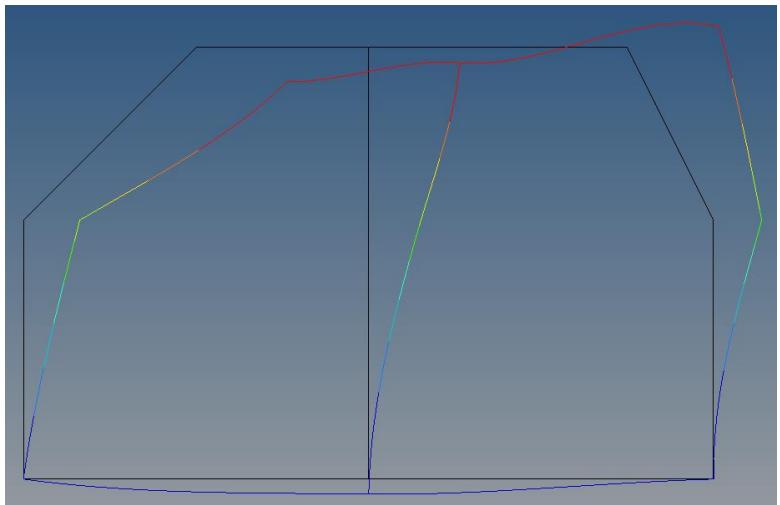
Rotate axis

$$(G_f)_{eff} = \left( \frac{1N}{0.002956mm} \right) \cdot \frac{1250mm}{2000mm} = 211.4N / mm$$

$$\delta = 0.002956mm$$

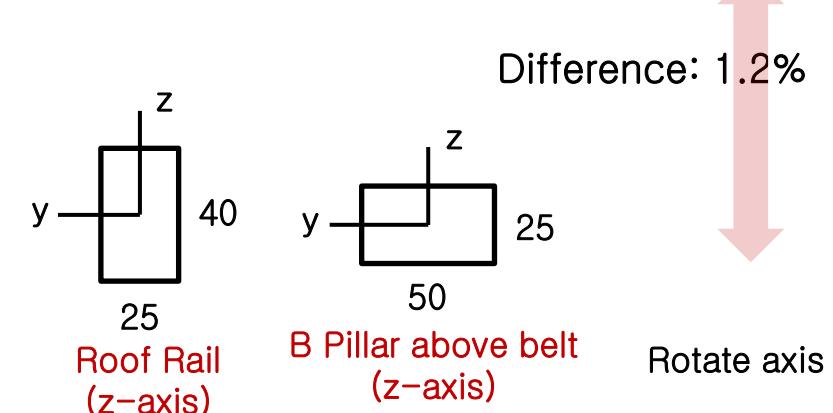
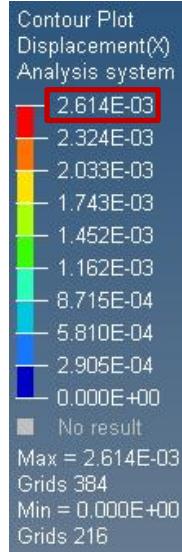
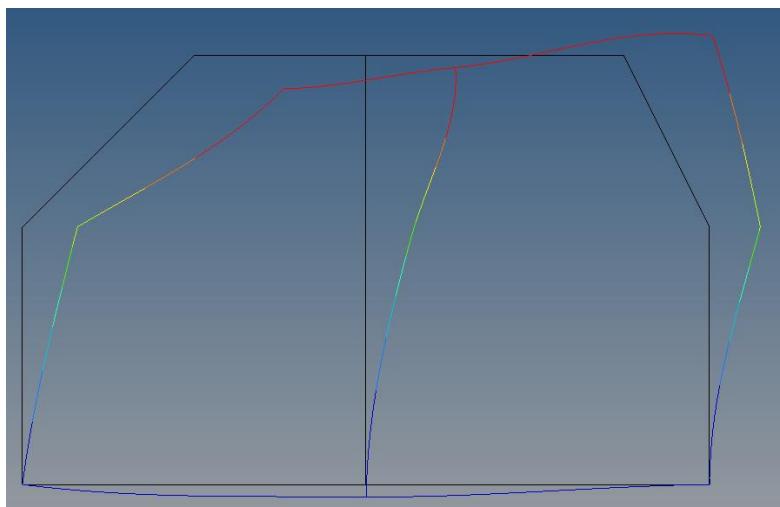
# EFFECT OF BEAM SECTION

- Side frame 모델 비교(effective shear rigidity): Roof Rail 및 B Pillar above belt 변경



$$(G_f)_{eff} = \left( \frac{1N}{0.002647mm} \right) \cdot \frac{1250mm}{2000mm} = 236.1N / mm$$

$$\delta = 0.002647mm$$



$$(G_f)_{eff} = \left( \frac{1N}{0.002614mm} \right) \cdot \frac{1250mm}{2000mm} = 239.1N / mm$$

$$\delta = 0.002614mm$$