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Comparative Study of Structural and Sheetmetal Combination Bracket on Elevator Rail System

Sumit V. Dubey[1], **Santosh B. Rane**[2]

[1] MTech Scholar, Sardar Patel College of Engineering, Munshi Nagar, Andheri –West, Mumbai -400058
email: sumitvdubey@gmail.com,
[2]Associate Professor, Department of Mechanical Engineering, Sardar Patel College of Engineering,
Munshi Nagar, Andheri –West, Mumbai-400058
email: s_rane@spce.com

Abstract.
Context: - Combination brackets are applied for fixing car and counterweight guide rails on the hoistway wall to deliver smooth and safe travel for side counterweight position.
Purpose: - The main intent of this work study is to compare the deflection and stresses value of the structural and sheet metal Combination bracket arises due to effect of forces imposed on the guide rail by the Car guide shoe.
Methodology: - Finite element method was performed for Structural and Sheet metal combination bracket to evaluate stress and deflection using SolidWorks Simulation software. Analytical calculation has been performed to calculate the forces acting on rail considering the case of safety gear operation as per EN 81-1
Research findings: - From this analysis, it has been found that structural combination brackets are stiffer compare to those made up of sheet metal.
Limitations: - Stress and deflection values shall be varied for different car cabin sizes. A case study of Car Size 1100x2000 mm for 13 passenger capacity rated load has been considered.
Originality/value: - This analysis results provides the possibility of selecting most reliable rail bracket for guide rail fixation.

1. Introduction

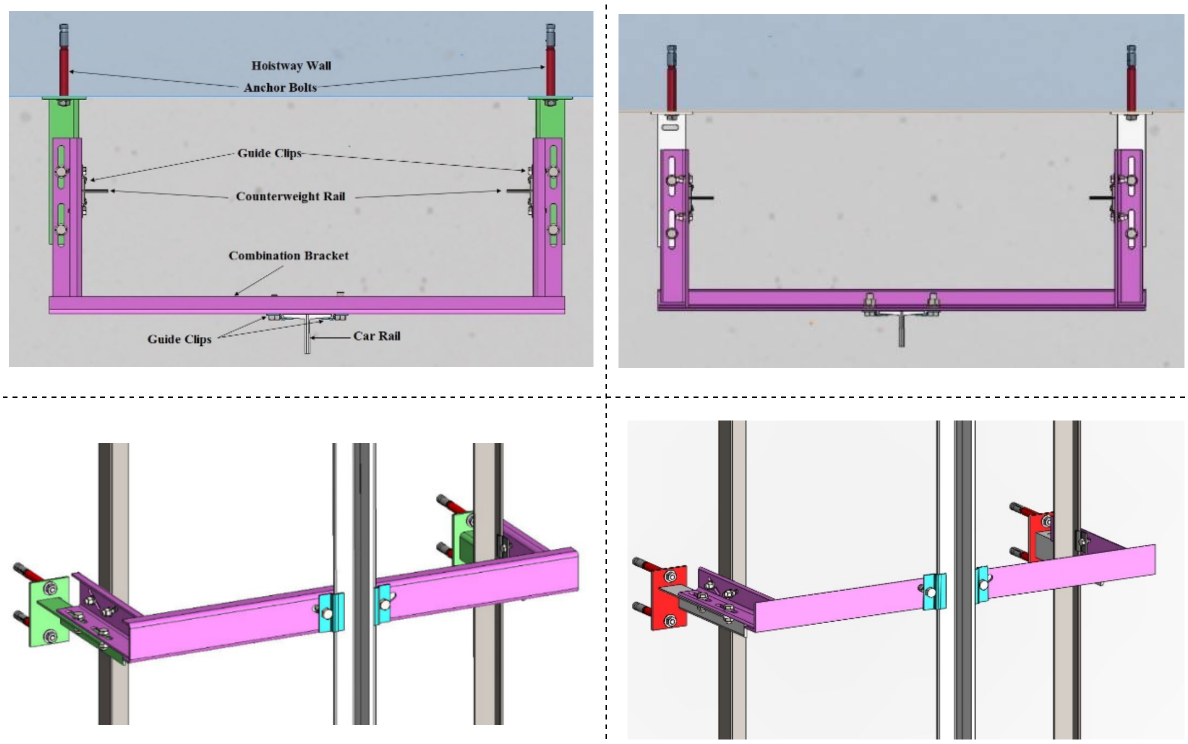
The elevator is a vertical transportation equipment that transfers the passenger and goods safely and efficiently between floor of a building. The main components of the elevator system are car cabin and frame, counterweight frame, rail and bracket system, traction machine, controller and landing doors and car doors. Combination bracket is used to fix one rail of the car and both rails of counterweight. It is mounted on the hoistway wall at definite interval regulated by rate load (no. of passenger) and car and counterweight mass. Certain elevator companies are using structural and fabricated type of combination as per their requirement. In this study, a comparison of structural and fabricated combination bracket is analysed. The stresses and deformations occurring on the combination brackets have been determined by using finite element method considering the rail forces calculated in case of safety gear actuation using the rules of EN 81-1.

2. Literature Review

Targit, 2002 reviewed that the force arises due to load acting on the car rail is from safety gear during safety gear actuation. Hayder F. Neamah., 2009 suggested the analytical calculation of the guide rail is the most accepted and justified method for guide rail analysis. Suhan Atay, 2013 analyzed the stresses and deflection of the guide rail, rail brackets and sliding clips. Elmali examined the stress and deflection of the guide rail resulted from distinct loading cases and forces acting on certain specific points between two guide rail fixing brackets.

3. Concept Model: Guide Rail and Combination Bracket

The Elevator system consists of guide rail and brackets to withstand the application of car and counterweight, when stopping the elevator car and its rated load or the balancing weight. These guide rails are attached to rail brackets through mean of guide clips and hardware accessories. Rail brackets are further reinforced on the hoistway wall through dash fasteners to provide adequate support to guide rail, thus forming an essential element of the complete rail system. Combination bracket is applied when the position of the elevator car and counterweight are adjacent and perpendicular to each other at a particular specified point. Two counterweight rail and one car rail are fixed and supported on combination brackets. The Concept model consists of two models as shown below in figure: a) Fabricated Combination bracket. b) Structural Combination bracket.



(a) Sheetmetal combination brackets | (b) Structural combination brackets

Figure 1. Guide rail and bracket assembly

4. Guide Rail Calculation

As per EN 81-1, Forces exerted on guide rail by Car are calculated by considering two operating conditions:

a) Normal running conditions.
b) Safety gear actuation conditions.

In our study, we perform the analytical calculation of the forces as per safety gear actuation condition which is a worst-case condition that determine the stiffness the rail. Since the car rail is fixed at the center of combination bracket, the configuration of centrally guide and suspended case of the elevator will be considered. The load is considered to be dispersed to the one-third area of the car cabin. The force obtained in the guide rail calculations are used as a reference in the FEM model. For 13 Pax

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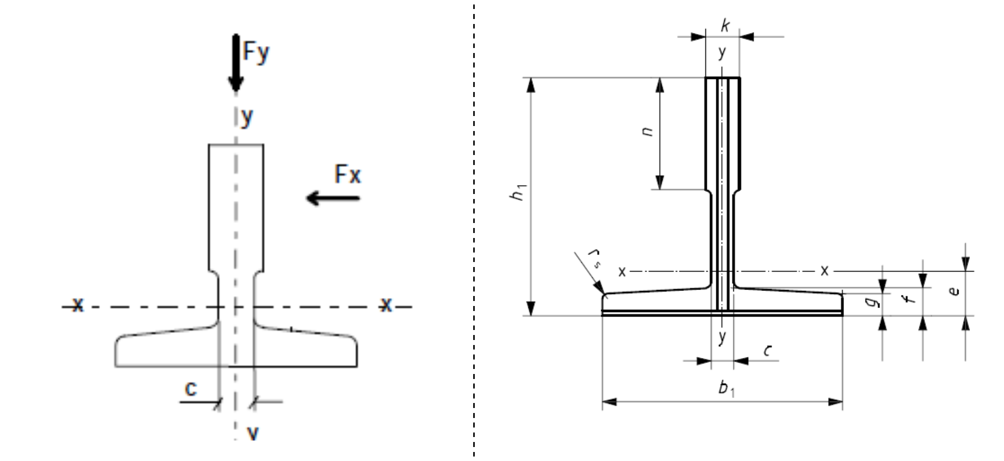
capacity elevator travel height is considered for 20 meters, the stresses and deflection to be used in guide rail will be calculated in accordance with EN81-1. The data given to be used in calculations are given below.

Table 1: Input Parameters for guide rail calculations

Parameters	Abbreviation	Value
Total car empty Load	P	: 1200 Kg
Rated load	Q	: 13x68=884 Kg
Weight at Cwt side:	M_{cwt}	: 1642 Kg
Travel rise:	TH	: 20 m
Car Cabin dimensions:	Dy ×Dx	: 1100×2000 mm
Car Guide Rail:	-	: T82/B
Distance between sliding guide shoes	h	: 3418 mm
Distance between combination brackets	L	: 2500mm
No of Guide rail	n	: 2
Guide rail properties	-	: Shown in figure 2



b=82
h=68
k=9
n=34
c=7.5
f=8.25
g=6
r_s =3

Figure 2. Dimensions of Guide rail in mm

4.1. Technical characteristic of the guide rail.

Cross-sectional area of a guide rail (S): 1091 mm^2

Linear density of a finished guide rail (q1):8.564 Kg/m

Distance from the rear surface to the centre of gravity of the guide rail (e):20.34 mm

Moment of inertia of the cross-sectional area of the guide rail related to the x-x axis (I_{x-x}): 493100 mm^4

Cross-sectional area modulus related to the x-x axis (W_{x-x}): 10270 mm^3

Radius of gyration corresponding to the x-x axis (i_{x-x}): 21.26 mm

Moment of inertia of the cross-sectional area of the guide rail related to the y-y axis (I_{y-y}): 301700 mm^4

Cross-sectional area modulus related to the y-y axis (W_{y-y}): 7358 mm^3

Radius of gyration corresponding to the y-y axis (i_{y-y}): 16.63 mm

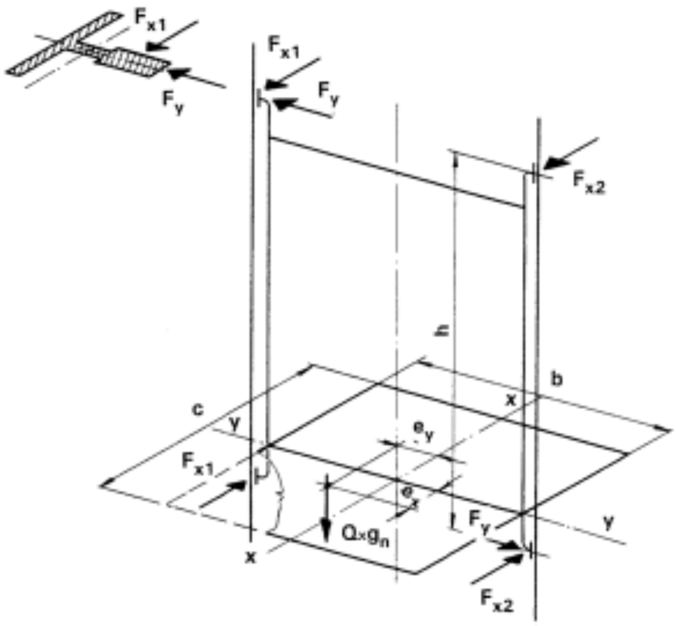


Figure 3. Forces acting on a guide rail

4.2. Centrally guided and suspended car.
The load distribution on the carriage and the cabinet measures are shown in Figure 3. P and Q are on the same side. For this reason, Q is on the x-axis

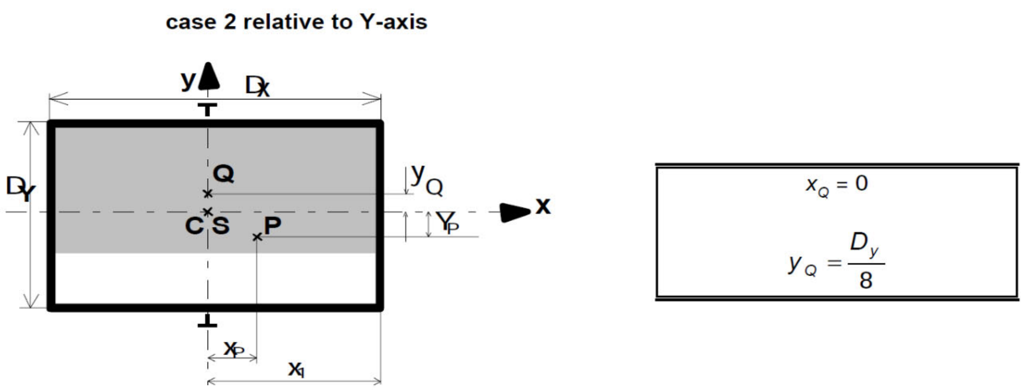


Figure 4. Load distribution case with relative to Y-axis

$X_Q = 0$, $Y_Q = \frac{Dy}{8} = \frac{1100}{8} = 137.5$ mm, $X_P = 50$ mm, $Y_P = 30$ mm

4.3. Safety gear operation.
The guide rail is safe when the permissible stress (σper) is 205 N/mm^2 for St37

4.3.1. Bending stress

a) Bending stress with respect to Y-axis of the guide rail due to guiding force:

$$F_x = \frac{K1.g.(Q.XQ+P.\ XP)}{(n.h)} = \frac{2 \text{ x } 9.81 \text{ x } (884 \text{ x } 0+1200 \text{ x } 50)}{(2 \text{ x } 3418)} = 172.2 \text{ N}$$

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$M_y = \frac{3.Fx.L}{16} = \frac{3 \text{ x } 172.2 \text{ x } 2500}{16}$ = 80,718.75 N-mm

$\sigma_y = \frac{My}{Wy} = \frac{80718.75}{7358}$ =10.97 N/mm^2

b) Bending stress with respect to X-axis of the guide rail due to guiding force:

$F_y = \frac{K1.g.(Q.YQ+P.YP)}{(n.h)/2} = \frac{2 \text{ x } 9.81\ (884 \text{ x } 137.5 + 1200 \text{ x } 30)}{(2 \text{ x } 3418)/2}$ = 904.36 N

$M_x = \frac{3.Fy.L}{16} = \frac{3\text{x } 904.36 \text{ x } 2500}{16}$ = 4,23,918.75 N-mm

$\sigma_x = \frac{Mx}{Wx} = \frac{423918.75}{10270}$ = 41.28 N/mm^2

The combine bending stresses acting on the guide rail.

$\sigma_m = \sigma_x + \sigma_y$ = 41.28 +10.97 = 52.25 N/mm^2 < σ_{per} =205 N/mm^2

Hence, Guide rail is safe.

4.3.2. Buckling stress calculation

$F_k = \frac{K1.g.(P+Q)}{n} = \frac{2 \text{ x } 9.81\ (1200+884)}{2}$ = 20,444 N

The omega value is taken from the table G.3 EN81 by evaluating since

$\lambda = \frac{Lk}{imin} = \frac{2500}{16.63}$ =150.33

Since R_m = 370 N/mm^2 , ω =4.33 from the table G.3 from EN81

M = 50 Kg because there is auxiliary equipment with guide rail installed;

$\sigma_k = \frac{(Fk+K3.M)\omega}{A} = \frac{(20444+1.2 \text{ x } 50\text{x } 9.81)\text{x } 4.33}{1091}$ = 83.47 N/mm^2

σ_k= < $\sigma_{per,}$ Hence, Guide rail is safe.

4.3.3. Combined stress calculation

Combined bending and compressive stress are given by

$\sigma = \sigma_m + \frac{(Fk+K3.M)}{A}$ = 52.25+ $\frac{(20444+1.2 \text{ x } 50 \text{ x } 9.81)}{1091}$ = 71.52 N/mm^2

σ= < $\sigma_{per,}$ Hence, Guide rail is safe.

Combined bending and buckling stresses are given by

$\sigma_c = \sigma_k + 0.9\sigma_m$ = 83.47 + 0.9 x 52.25 =130.495 N/mm^2

From Table 5.6, in the case of safety equipment operation,

σ_c = < $\sigma_{per,}$ Hence, Guide rail is safe.

4.3.4. Bending stress calculation at the guide rail neck

Bending stress in the rail neck, which occurs in the T-profiled guide rail, using Equation (5.12) from EN81;

$$\sigma_f = \frac{1.85.Fx}{c2} = \frac{1.85x\ 172.2}{7.5x\ 7.5} = 5.66\ N/mm2$$

4.3.5. Deflection in the Guide rail

Using the equation (5.13a) from EN81, the deflection in the guide rail in the X-X plane,

$$\delta_x = \frac{0.7.Fx.l3}{48.E.Iy} = \frac{0.7x172.2x\ 2500x2500x2500}{48\ x\ 208000x301700} = 0.63\ mm$$

Using the equation (5.13b) from EN81, the deflection in the guide rail in the Y-Y plane,

$$\delta_y = \frac{0.7.Fy.l3}{48.E.Ix} = \frac{0.7\ x\ 904.36x\ 2500x2500x2500}{48\ x\ 208000\ x\ 493100} = 2.00\ mm$$

5. FEM Model

Finite element model of guide rail and combination brackets are created using SolidWorks simulation software. Design parameters previously used in analytical calculations are considered in FEM modelling. Table 2 shows that 4 cases were considered while applying forces at the interface of guide for both types of combination bracket and the value of lateral forces Fx, Fy and vertical force Fk are taken from analytical calculation. The material for combination brackets is shown below in the table 3. Contact properties between the components are defined as global bonded conditions. Friction coefficient between the elevator component is assigned. The holes (at which wall fasteners is fixed) in rear surface of combination bracket in contact with the wall is considered as fixed geometry and two virtual wall conditions are applied, one vertically and other on the pit floor on which rail is mounted. All the structural, Sheetmetal and machine components are treated as a solid element for 4 cases. The contact between the rail and combination bracket front surface is given bonded relation since they are fixed with each other with bolt. Details for Mesh information is shown in table 4

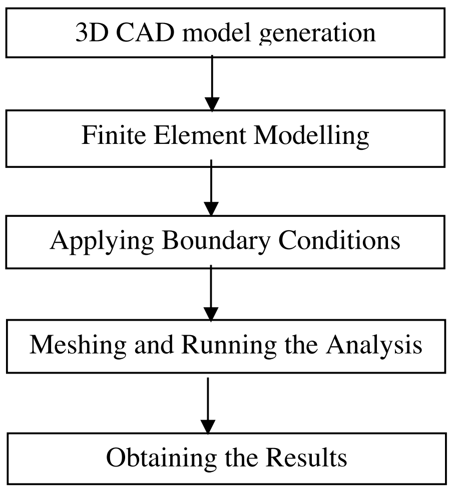
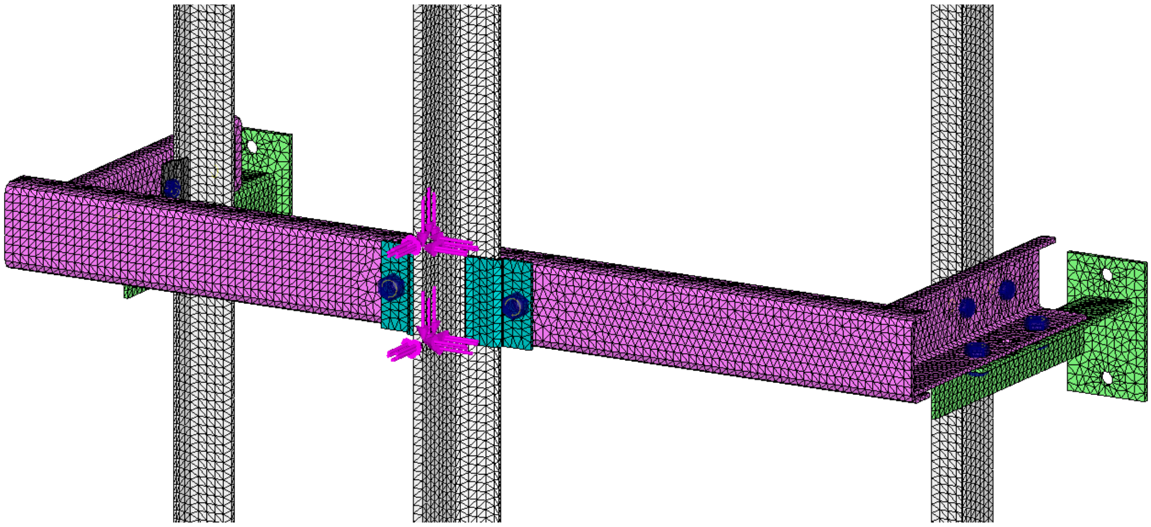


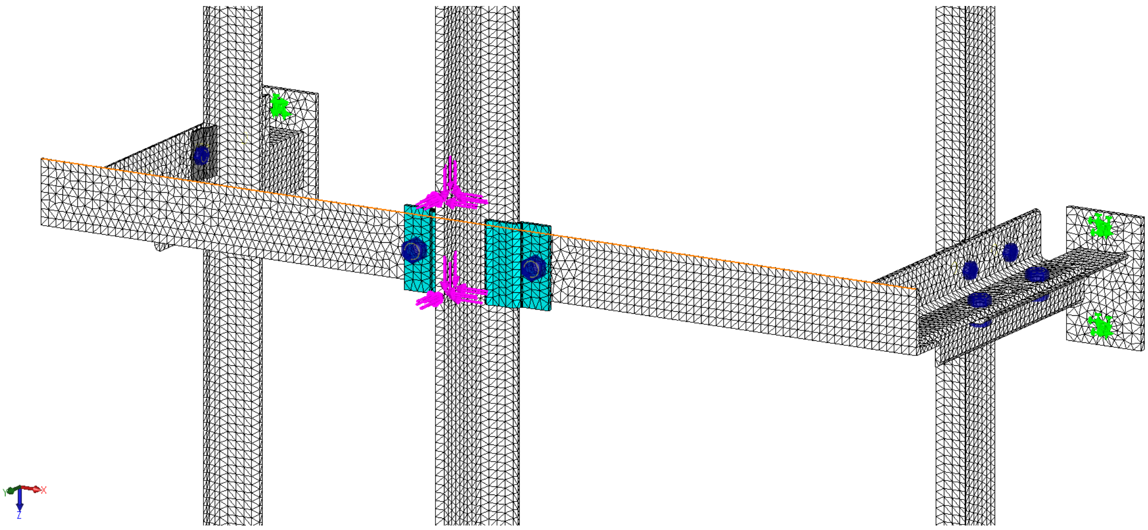
Figure 5: Flow chart for stress analysis of Combination bracket

Table 2: Boundary condition cases

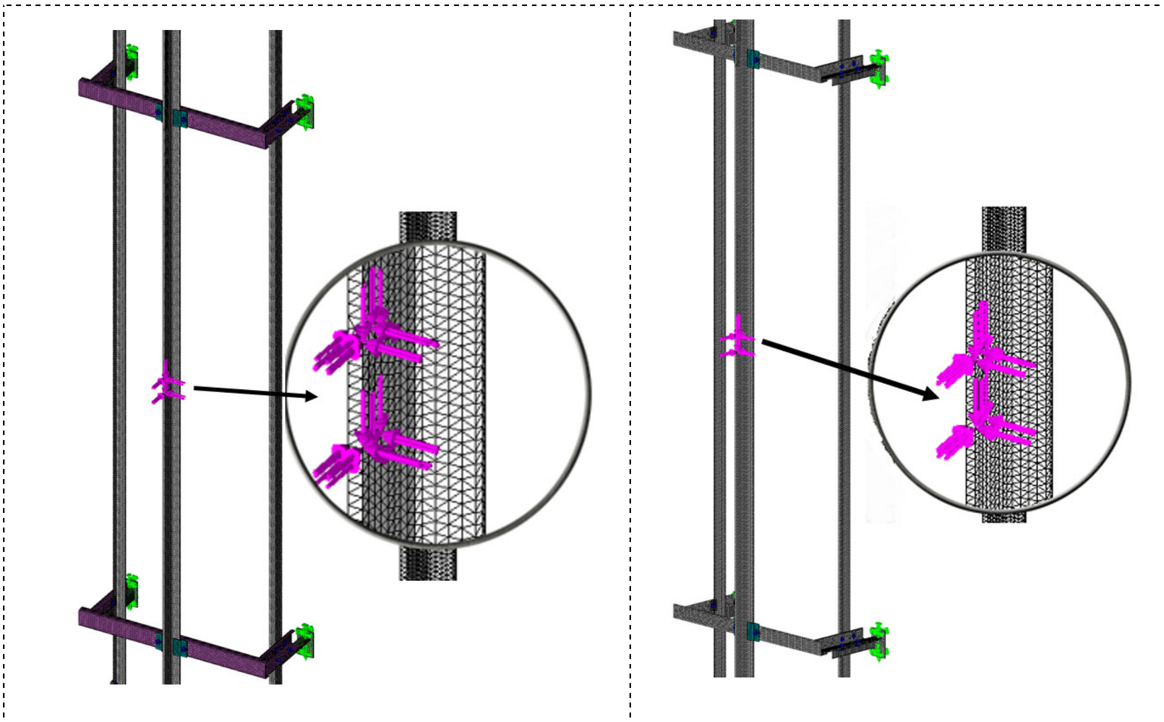
Case 1: Forces applied on guide at the junction of Guide rail bracket (Sheetmetal)



Case 2: Forces applied on guide at the junction of Guide rail bracket (structural)



Case 3: Forces applied on guide rail between two brackets (Sheetmetal)	Case 4: Forces applied on guide rail between two brackets (structural)



The material selected for the guide rail is as per IS 2062 E250 A, for structural combination brackets is as per IS 2062 E275 BR and for Sheetmetal combination bracket is as per IS 1079_2009. The material characteristic is taken as linear isotropic.

Table 3: Material properties for Guide rail and brackets

Component Name	Structural Comb. Brackets	SM Comb. Brackets	Guide Rail
Material Name:	IS 2062 E275 BR	IS 1079_2009	IS 2062 E250 A
Model type:	Linear Elastic Isotropic	Linear Elastic Isotropic	Linear Elastic Isotropic
Yield strength:	255 N/mm^2	230 N/mm^2	230 N/mm^2
Tensile strength:	440 N/mm^2	440 N/mm^2	410 N/mm^2
Young's modulus:	210000 N/mm^2	210000 N/mm^2	210000 N/mm^2
Poisson's ratio:	0.28	0.28	0.28
Mass density:	7.8 g/cm^3	7.8 g/cm^3	7.8 g/cm^3
Thermal expansion coefficient:	1.3e-005 /Kelvin	1.3e-005 /Kelvin	1.3e-005 /Kelvin

Table 4: Mesh Information

Parameter	Sheetmetal	Structural
Mesh Type	Solid Mesh	Solid Mesh
Mesher Type	Standard	Standard
Jacobian points	4 Points	4 Points
Element Size	7 mm	7 mm
Tolerance	0.375 mm	0.375 mm
Mesh Quality Plot	Draft Quality	Draft Quality
Total Nodes	378583	394662
Total Elements	1144395	1189854
Maximum Aspect Ratio	41.082	43.648
% of elements with Aspect Ratio < 3	90.08	91

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The lateral force acting on guide rail and brackets does not change in accordance with deformation of the component and with time. Material property is elastic in nature. Hence, linear static analysis is selected for this study.

6. Analysis Results and Discussions

Results from finite element analysis is interpreted distinctively for various cases shown below. The stress and deflection in X and y directions are given in table 5. Finite element analysis has been performed considering safety gear actuation conditions in all cases

Case 1: Forces applied on guide at the junction of Guide rail bracket (Sheetmetal)	Case 2: Forces applied on guide at the junction of Guide rail bracket (structural)
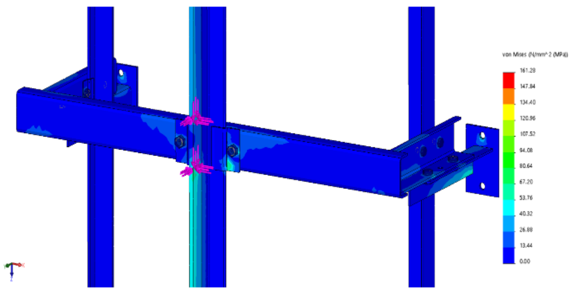	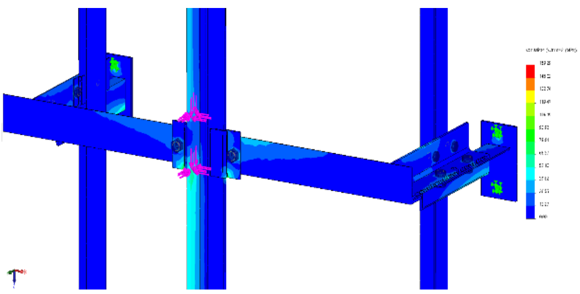
Figure 6.1(a) Von Mises Stress	**Figure 6.2(a)** Von Mises Stress
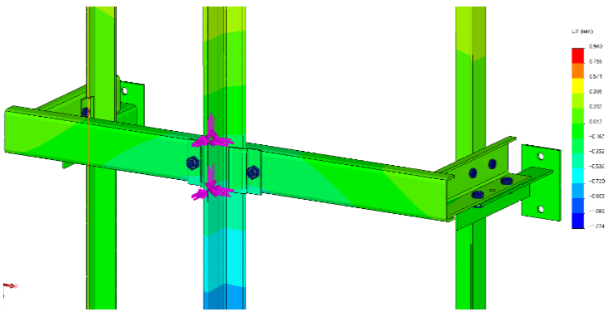	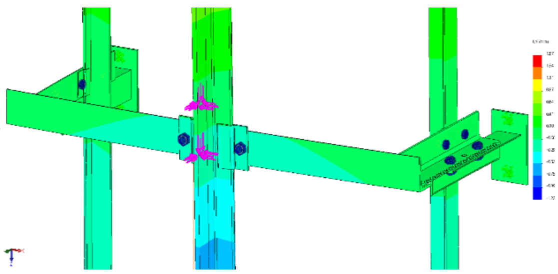
Figure 6.1(b) Deflection in Y axis	**Figure 6.2(b)** Deflection in Y axis
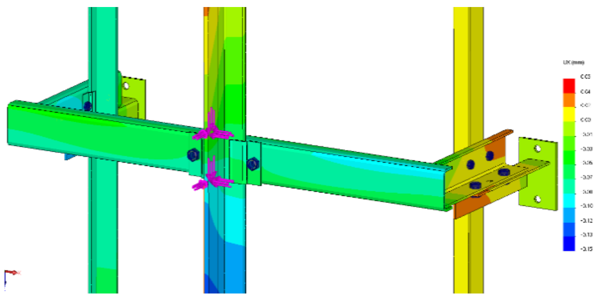	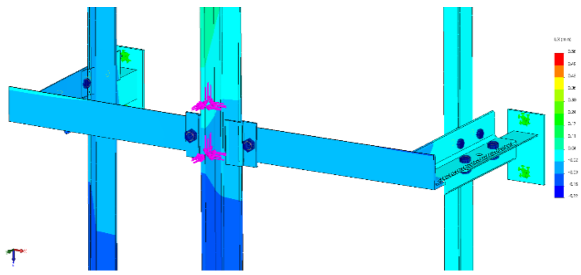
Figure 6.1(c) Deflection in X -axis	**Figure 6.2(c)** Deflection in X -axis

Von Mises Stress	Deflection in Y axis	Deflection in X axis

Case 3: Forces applied on guide rail between two brackets (Sheetmetal)

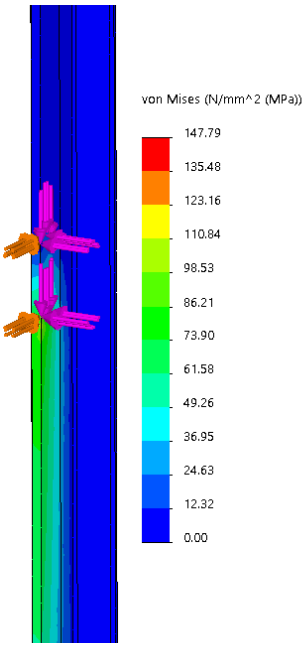

Figure 6.3(a)

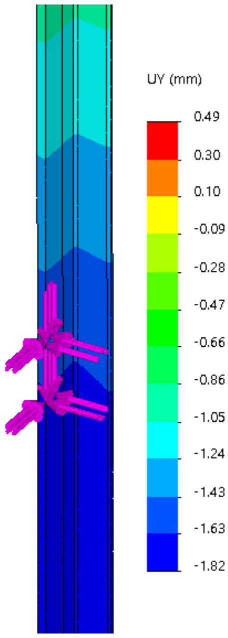

Figure 6.3(b)

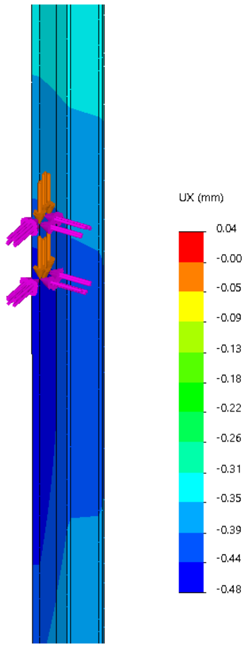

Figure 6.3(c)

Case 4: Forces applied on guide rail between two brackets (Structural)

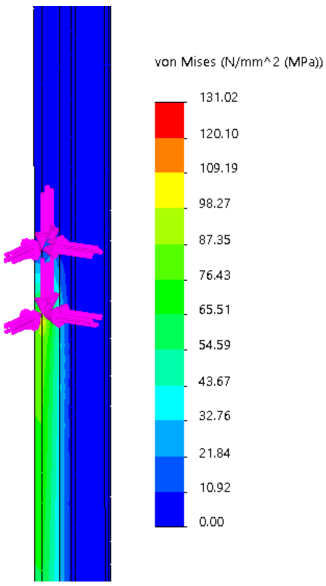

Figure 6.4(a)

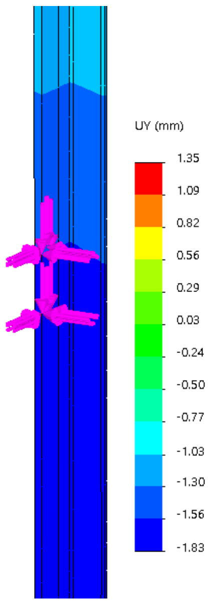

Figure 6.4(b)

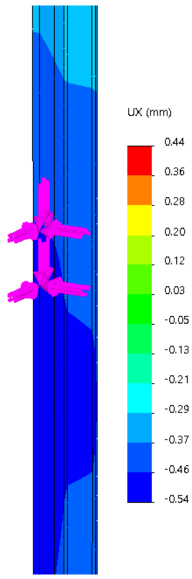

Figure 6.4(c)

Stress distribution and deflection for Y axis values for case 1 and case 2 are compared with each other and are found to be nearly same. Case 3 and 4 stress and deflections values in x and y direction results are compared analytical calculation

Table 5: Analysis results

Analysis Type	Stress (N/mm^2)	Deflection in Y axis (mm)	Deflection in X axis (mm)
FEA (Case 1)	161.28	1.27	0.15
FEA (Case 2)	159.29	1.22	0.22
FEA (Case 3)	147.79	1.82	0.48
FEA (Case 4)	131.02	1.83	0.54
Analytical	130.49	2.0	0.63

7. Conclusion

The following points may be concluded:

- From case 1 and 2, Stresses distribution and maximum deflection values at guide rail fixed on structural combination and Sheetmetal combination brackets are nearly same.
- From case 3 and 4, Stresses distribution for the case, guide rail fixed between two structural combination is less than that fixed between two Sheetmetal combination brackets. maximum deflection values for both cases remains the same in y axis.
- The results obtained from analysis will help in determining the material selection in early steps of design evolution, thus saving development time and further resulting in decision-making process to optimize the design. However, Cost of the raw material may differ as per organizational sourcing.

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