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Analytical Optimization of Chassis Frame for 40ft Dual-Axle Flatbed Trailer Design

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Abstract: *This article will review a design and analysis study that reduces trailer chassis mass while minimizing the total cost impact. Design approaches, material selections and proposed section were reviewed. The Trailer chassis main member were quantified and summarized to create an overall mass and weighted cost estimate for a low mass Trailer.*
Keywords: *Optimization, Chassis frame, Flat bed trailer, Shear stress*

I. INTRODUCTION

India Truck Industry, also known as Road Goods Transport Industry (RGTI) or Indian trucking industry, has played a major role in the Indian trade and commerce for the decades. Along with railways, Indian truck industry has also played an instrumental role in moving goods form one part of the country to another. From 1950-51 to 1990-91, the truck industry in India has seen a growth rate of 7.2%. Currently, there are more than 1300 trucks per million population, whereas the utilization of trucks is more than 70,000 kms per annum.

The reason behind the success of India truck industry is the added advantage of road transport over the railways. Trucks can accept goods in small quantities, can reach rural and hill areas, and also require less time than the rail for loading and unloading of goods. As a result, India truck industry cemented its place in goods transportation. With passage of time, truck industry in India has involved a good number of Indian automobile giants including Tata Motors, Hindustan Motors, Ashok Leyland, Mahindra and Mahindra, Force Motors, Swaraj Maza, Eicher etc.

Due to increase in the fuel prices and all it is now necessary to make the trucking less costly. By making the trailers economic is one way of doing it. This project is the effort to do the same. By reducing the dimensions of the trailer parts such as beam the reduction of weight is possible which will consequently cause the reduction in the cost of trailer.

The trailer given is 40 ft dual axle semi trailer. The objective is to reduce the weight of the trailer by 10 %. By selecting appropriate size of beams the objective is completed.

II. OBJECTIVE / PROBLEM STATEMENT

The objectives of this paper are:
i) To reduce the weight of the trailer by 10 %. By selecting appropriate size of main member beams the objective is completed.
iii) The Trailer chassis main member and cross member were quantified and summarized to create an overall mass and weighted cost estimate for a low mass Trailer.
iv) To develop a new trailer chassis.

III. ANALYTICAL APPROACH FOR OPTIMIZATION

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3.1. *Design Input: 40ft Dual-Axle Flatbed Trailer Design*

Load coming on each twist lock	=	4500 kg
Payload	=	4500 x 8
		36,000 kg
Gross vehicle weight of trailer	=	40,000 kg
Overall length of trailer	=	12,135 mm
Overall width of trailer	=	2550 mm

3.2 *Load Distribution On Kingpin And Rear Axle Centerline Chart*

Sr.No.	Title	Weight (kg)	Load on Kingpin (R_k) kg	Load on rear axle centre line (R_A) kg
1	Load on rear side (4.5T x 2) (Right side)	9000	-	9000
2	Load on front side (4.5T x 2) (Right side)	9000	9000	-
3	Load on centre left (case1)	9000	3520	5480
4	Load on centre right (case2)	9000	3227	5773
5	Self weight of chassis frame	4000	1643	2357
		40,000	17,390	22,610

Table 1 – load distribution chart on kingpin and rear axle

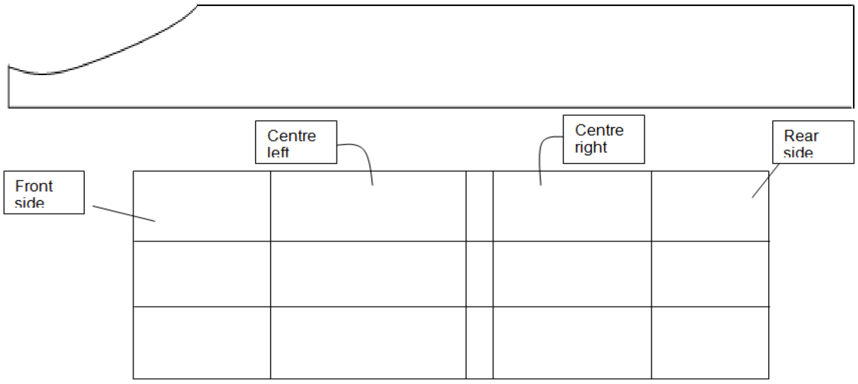


Fig1. Trailer front and top view

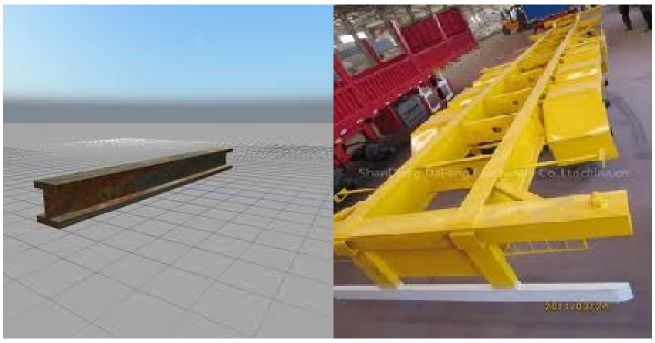


Fig.2: Main member design

3.3 STUDY OF DIFFERENT PROPOSED SECTIONS OF COMPANIES WORLD OVER

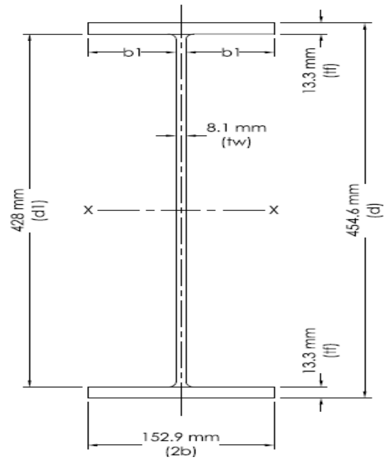
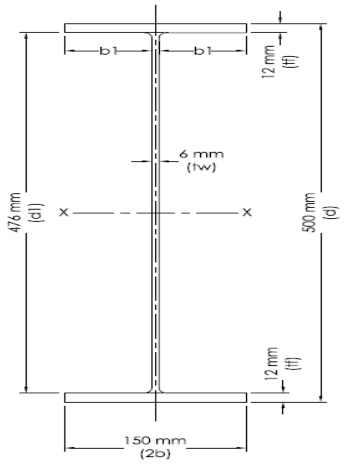
Subject	**Existing Section**	**Proposed Sections**			
		I	**II**	**III**	**IV**
Top Width (mm)	152.9	150	140	146	140
Top Thickness (mm)	13.3	12	14	14	14
Web Thickness mm)	8.1	6	6	6	6
Bottom Width(mm)	152.9	150	140	146	140
Bottom Thickness mm)	13.3	12	16	16	16
Total Height (mm)	454.6	500	500	500	505
Area(cm^2)	**76.23**	**64.56**	**70.20**	**73.20**	**73.50**

Section selected – <u>Section I with web of 6 mm</u>

Refrence

Proposed Sections		CNHTC.Fujian special Vehicles co.Ltd. (made-in-china.com)
	•	Hubei Mingren Donfang Industry co.Ltd. (www.himfr.com)
	•	Wall cargo semitrailer (factory.dhgate.com)

3.4 Section Selection

Subject	**Existing Section**	**Proposed Section**
Figure		
Selected Material	St-52-3U	St-52-3U
Ultimate Tensile Strength	490 N/mm^2 (49.94 kg/mm^2)	490 N/mm^2 (49.94 kg/mm^2)
Yield Strength	355 N/mm^2 (36.18 kg/mm^2)	355 N/mm^2 (36.18 kg/mm^2)
Area of Section	76.23 cm^2	64.56 cm^2
Section Modulus	1122 cm^3	1073.2 cm^3
Moment of Inertia	25500 cm^4	26830 cm^4

3.5 Calculations Of Proposed Section:

Area	= = = = =	$[(2b \times t_f) \times 2 + (d_1 \times t_w)]$ $[(150 \times 12) \times 2 + (476 \times 6)]$ 3600+3808 6456 mm^2 64.56 cm^2
Moment Of Inertia (I_{xx})	= = = =	$[(1/12) \times 2b \times d^3] – [(1/12) \times (2b – t_w) \times d_1^3]$ $[(1/12) \times 150 \times 500^3] – [(1/12) \times (150–6) \times 476^3]$ $156250 \times 10^4 – 12942 \times 10^4$ 26830×10^4 mm^4
Section Modulus (z_{xx})	= = = = = =	$[(1/6) \times 2b \times (d^3/d)] – [(1/6) \times 2b_1 \times (d_1^3/d)]$ $[(1/6) \times 2b \times d^2] – [(1/6) \times 2b_1 \times (d_1^3/d)]$ $[(1/6) \times 150 \times 500^2] – [(1/6) \times 144 \times (456^3/500)]$ $6250 \times 10^3 – 5176.80 \times 10^3$ 1073.2×10^3 mm^3 1073.2 cm^3

IV. Calculations Of Shear Stresses

Maximum shear stress

Maximum intensity of Shear stress will occur at the neutral axis. The shear stress is given by,

$$\tau = \frac{s.ay}{Ixx*tw}$$

Where,

S = Maximum shear force, kg.

ay = Moment of the area above neutral axis, about the neutral axis.

I_{xx} = Moment of inertia, mm^4.

t_w = Breadth of web, mm.

(Moment of the area above neutral axis = 150x12x244 + 6x238x119
And about the neutral axis)

= 60.91×10^4 mm^3

Maximum shear stress τ_{max} = $(900 \times 60.91 \times 10^4) / (26830 \times 10^4 \times 6)$

= 3.40 kg/mm^2

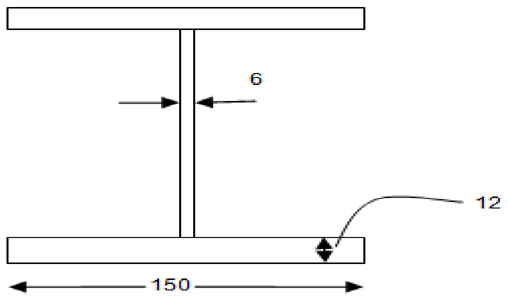


Fig.3: Beam with dimensions

Shear stress just above the junction of the flange and web
(Shear stress in the Flange in the web at 238 mm from neutral axis)

$$\tau = \frac{s.ay}{Ixx*2b}$$

= 9000 x {150x12x [(12/2) +238]} / (26830x10^4x150)
= 0.09 kg/mm^2

Shear stress just below the junction of the flange and web
(Shear stress in the Web at 238 mm from neutral axis)

$$\tau = \frac{s.ay}{Ixx*tw} = 9000 \text{ x } \{150\text{x}12\text{x } [(12/2) +238]\} / (26830\text{x}10^4\text{x}150)$$

= 2.25 kg/mm^2

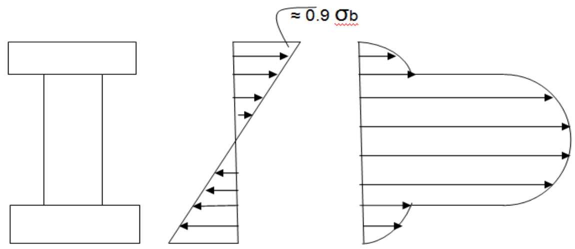
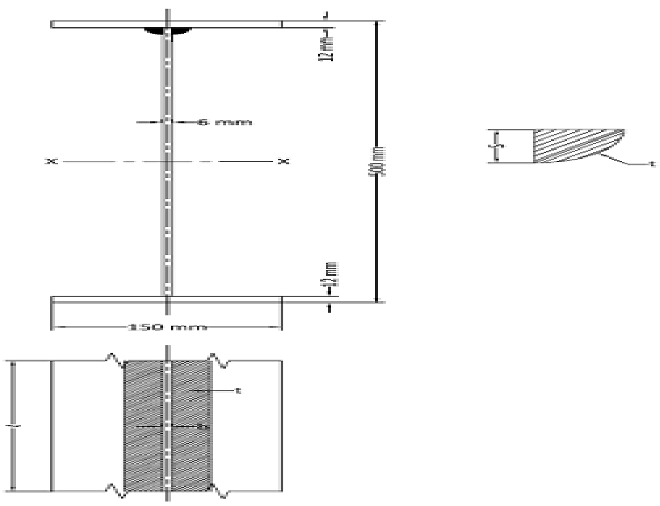


Fig.4 Shear and Bending Stress Distribution diagram

%Reduction in Area
= Area of existing section – Area of proposed section / area of existing section
= [76.23 – 64.56 / 76.23] * 100
= 15 %

V. Weld Size Calculations At The Junction Of Flange Plate And Web Plate

4.1 Input Data:



Maximum bending moment (M)	=	148×10^5 kg-mm. (from fig.2)
Web thickness (b)	=	6 mm.
Length of the weld (l)	=	12135 mm. (from fig.1)
Allowable bending stress in weld (σb)	=	15 kg/mm^2

Case I: Weld material of allowable bending stress 15 kg/mm^2

i) Required Section Modulus:

Formula:

$Z_R = M_w / \sigma b$ ……[Ref. Eqn. (2.5)-Strength of materials by Nirali Publication]

Where,

M_w = Bending Moment at the welding section, kg-mm

= Maximum Bending moment x 0.9 (from fig.5)

$= 148.26 \times 10^5 \times 0.9$

$= 133.43 \times 10^5$ kg-mm

:. $Z_R = M_w / \sigma b$

$= (133.43 \times 10^5) / 15$

$= 8.89 \times 10^5$ mm^3

:. Required Section Modulus is 8.89×10^5 mm^3

ii) Available Section Modulus:

Formula:

$Z_A = t \times b \times l$

$Z_A = t \times 6 \times 12135$

$= 72810\ t$

iii) Weld leg calculation:

For weld leg calculation we put following condition,

Available Section Modulus = Required Section of Modulus

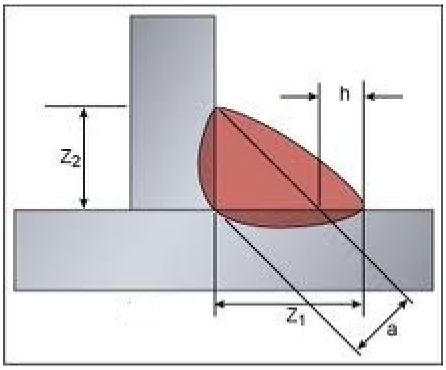
$(Z_A) = (Z_R)$

$72810 \times t = 8.89 \times 10^5$

$t = 12.20$ mm $\approx$ 13 mm

:. Weld throat (t) = weld leg (s) = 13 mm ….. (From input data)

The weld leg is 13 mm for allowable bending stress of 15 kg/mm^2 of the weld



Case II: Weld material of allowable bending stress 16 kg/mm^2

i) Required Section Modulus:

Formula:

$Z_R = M_w / \sigma b$

Where,

M_w = Bending Moment at the welding section, kg-mm

= Maximum Bending moment x 0.9 (from fig 5)

$= 148.26 \times 10^5 \times 0.9$

$= 133.43 \times 10^5$ kg-mm

:. $Z_R = M_w / \sigma b$

$= (133.43 \times 10^5) / 16$

$= 8.33 \times 10^5$ mm^3

:. Required Section Modulus is 8.33×10^5 mm^3

ii) Available Section Modulus:

Formula:

$Z_A = t \times b \times l$

Z_A = t x 6 x 12135
= (72810 x t) mm^3
iii) Weld leg calculation:,
For weld leg calculation we put following condition,
Available Section Modulus = Required Section of Modulus
$(Z_A) = (Z_R)$
72810 x t = 8.33 x 10^5
t = 11.45 mm ≈ 12 mm
:. Weld throat (t) = weld leg (s) = 12 mm ... (From input data)
The value of weld leg is 12 mm for allowable bending stress of 16 kg/mm^2 of the weld
4. EXISTING MIDDLE AND SIDE CROSS MEMBERS DESIGN

Fig.7 Cross Member

A) Input Data:

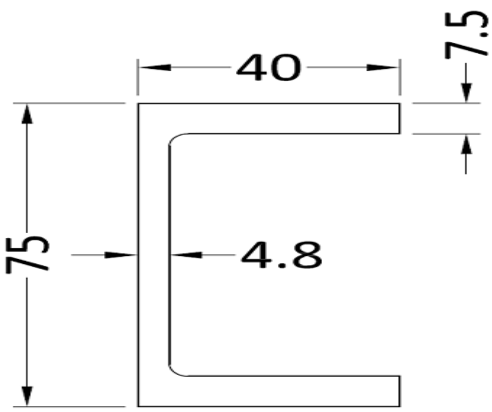


Fig.8 existing cross member

Section: ISMC – 75x40x4.8thk x 7.14 kg/m

Weight per unit length	= 7.14 kg/m	(IS:808)
Moment of inertia (I_{xx})	= 78.5 cm^4	(IS:808)
Section of modulus (Z_{xx})	= 16.14 cm^3	calculated in calculations
Area of section	= 9.1 cm^2	(IS:808)
Load on Member	= 1166 kg	Given

4.1 Calculations Of Existing Middle And Side Cross Member
1) Shear stress on beam
Shear stress on beam (**τ**) = (w x A) / 2
τ = 1166 / 2 x 9.1 x 100
= 0.64 kg/mm^2
2) Bending moment
Bending moment (M) = w x l / 12
= 1166 x 950 / 12

= 92308.33 kg-mm
= 92.3 kg-m

3) Section of Modulus
Section of modulus (z_{xx}) = I_{xx} / (H/2)
= 78.5 / 3.75
= 20.96 cm^3
= 20966.66 mm^3

4) Bending stress
Bending stress σb = Bending moment (M) / Section of modulus (z_{xx})
= 92308.33 / 20966.66
= 4.4 kg/mm^2

4.2 PROPOSED MIDDLE AND SIDE CROSS MEMBER CALCULATIONS
Input data:

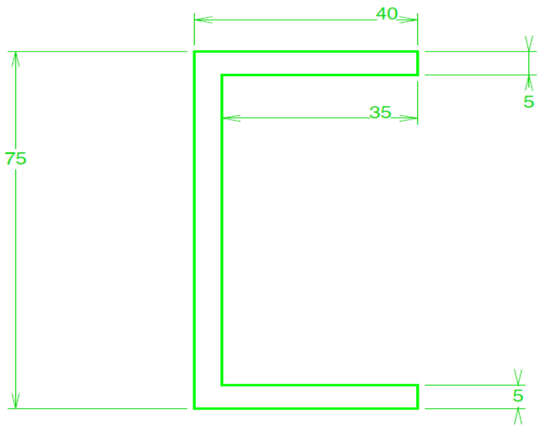


***Fig*.9 Proposed cross member**

Section: ISMC – 75x40x5thk x 6.08 kg/m

Weight per unit length	= 6.08 kg/m	…… (calculated in calculations)
Moment of inertia (I_{xx})	= 60.52 cm^4	... … (calculated in calculations)
Section of modulus (Z_{xx})	= 16.14 cm^3	……(calculated in calculations)
Area of section	= 7.75 cm^2	… ...(calculated in calculations

VI. Calculations

1) Area
Area = (75+40+40) x 5
= 775 mm^2
= 7.75 cm^2

2) Weight per unit length:
For area 9.1 cm^2 weight / unit length is = 7.14 kg/m
For area 7.75 cm^2 weight / unit length =?

weight / unit length for selected section = 7.75 x 7.4 / 9.1
= 6.08 kg/m

3) % Reduction in load:

$$= \frac{\text{weight per unit length of (existing section – proposed section)}}{\text{Weight per unit length of existing section}}$$

= 7.14 - 6.08 / 7.14
= 14.8 %

4) Bending moment
Bending moment (M) = w x l / 12
= 1166 x 950 / 12
= 92308.33 kg-mm

5) Section of Modulus

Section of modulus (z_{xx}) = ($BH^2/6$) – ($bh^3/6H$)
= ($40 \times 75^2 / 6$) – ($35 \times 65^3/6 \times 75$)
= 16140 mm^3

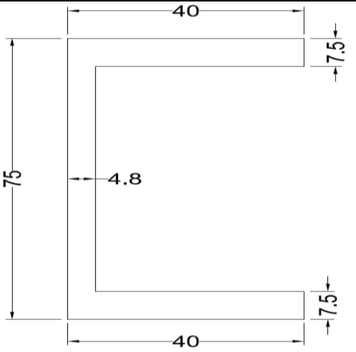
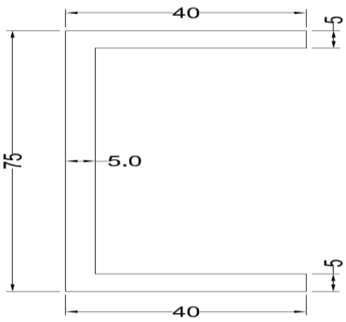
6) Moment of Inertia

Moment of inertia I_{xx} = Section of modulus x H/2
= 16140 x 75/2
= 605250 mm^4

7) Bending stress

Bending stress (σb) = Bending moment (M) / Section of modulus (z_{xx})
= 92308.33 / 16140
= 5.7 kg/mm^2

1. SUMMARY:

Subject	Existing Section	Proposed Section
Figure		
Section	ISMC – 75x40x4.8thk x 7.14 kg/m	ISMC – 75x40x5thk x 6.08 kg/m
Weight per unit length	7.14 kg/m	6.08 kg/m
Bending Stress	4.4 kg/mm^2	5.7 kg/mm^2
Area of Section	9.1 cm^2	7.75 cm^2
Section Modulus	20.96 cm^3	16.14 cm^3
Moment of Inertia	78.5 cm^4	60.52 cm^4
%reduction in weight	14.8%	

VII. CONCLUSION

1. A conclusion for main member by modifying the size of the existing section the weight is reduces up to 15 %.
2. The weld leg size for main member

Table – 5 Weld Leg Size

Case	Allowable bending stress in weld (kg/mm^2)	Required section modulus (mm^3)	Weld leg (mm)
I	15	8.89 $\times 10^5$	13
II	16	8.33 $\times 10^5$	12

3. For middle and side cross members by modifying the existing section the weight is reduced by 14.8%.
4. The weight of the trailer is reduced to make it economical.

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