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Design, Analysis and Fabrication of Agriculture Semi-Trailer

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Abstract

Tractor trailer is cost effective mode of transportation. It is generally used in transporting agricultural crops, building material and heavy machinery from one place to another place. It is generally manufactured by small scale industry but they are not considering technical details of it. There is lots of research done on trailer parts such as axle, chassis, leaf spring etc. but no such information available for complete design of trailer. Therefore, in this paper 3.5 tonne semi-trailer is designed by considering all the research work done previously and according to Indian Commercial Motor Vehicle rules. CATIA V5 software is used for designing of semi-trailer and ANSYS 2021 R1 is used for finite element analysis. Also, the chassis with “C” section cross bearer and “I” section cross bearer is compared.

Keywords: Semi-Trailer, Trolley, Design, Chassis, Axle, Ansys.

1. **Introduction:** Tractor Trailer is a good source of transportation which can transfer goods like agricultural crops, building construction material and other miscellaneous things from one place to other another place. Tractor trolley also known as trailers. Trailers are used in rural and urban areas but it's mostly used in rural areas. Trailers are basically in two types like semi-trailer and balanced trailer. Semi-trailer has two tyre and single axle while balanced trailers have four tyre and two axles. The main advantage of balanced trailer over semi-trailer is that because its load carrying capacity is high [1]. The main requirement of designing a trailer are easy to maintain, robust construction, longer working life etc. [2]. The trailers are available in 2, 3, 4, 5, 6, 8, 10 tonnes and more [3]. The capacity of semi-trailer should not be more than 5 tonnes while the capacity of trailer is more than 5 tonnes then it will come under balanced trailer.

Aloni et al. performed finite element analysis on existing axle shaft and observed that fatigue cracks are generated from transition areas due to sharp edges and produced modified axle using ductile material ASTM A536-84(2004) 65-45-12(EN1536:1997,EN-GJS-450-12, BS2789:1985-450/12) [4]. Patil et al. performed the finite element analysis of different cross section of trailer axle and found that I section channel have better results compare to others but it is not used in the industry because of non-uniform cross section. In this case we can consider the minimum deflection and stress value. The square cross section axle gives the best result [5]. Choudhary et al. designed semi-trailer Axle by using the computer aided engineering (CAE) and compare the result with circular Axle. The result shows that the deformation and stress generated in circular axle is less than square axle [6]. Manasa choose same material for axle shaft with different cross section and performed analysis by using ANSYS and found that round cross section axle shaft have better result than square cross section shaft [7]. V. R. Deulgaonkar performed a Finite element analysis of structure which is connected between chassis and trolley [8]. The purpose of this structure is to provide a support to the trailer during transportation in agricultural terrains. Tayade et al. designed a semi-trailer chassis using I section channel instead of C type of channel with keeping similar material and dimension and they found that the result of I section channel is better than C type channel [2]. Bankapur et al. performed a fatigue analysis on chassis trailer [1]. Shinde et al. used a C type cross section for chassis [9]. Dhoshi et al. used an analytical and finite element method on existing leaf spring of semi-trailer and result of this study shows that number of leaf spring reduced which result to reduction in the weight and production cost [10]. Yadav et al. used different material for leaf spring and performed finite element analysis by using ANSYS software and found that the material 55Si2Mn90 have better results in terms of deflection and stress on same input parameters [11].

2. **Material:** The role of material is very important while designing any component. The material for important component and axle assembly of trailer is shown in table 1 [3].

Table 1 Material and Grade Standard for Trailer Component [3].

S. No.	Components	Material	Ref to Indian Standard (IS) No.	Grade
1	Chassis	Mild Steel	IS 2062	Fe 410-S
2	Drawbar	Mild Steel	IS 2062	Fe 410-S
3	Tow eye	Carbon Steel	IS 1875	20 C
4	Platform	Mild Steel	IS 2062	Fe 410-S
5	Side board	Mild Steel	IS 2062	Fe 410-S
		Timber	IS 2179	
6	Leaf Spring	Spring Steel	IS 3431	-
7	Axle	Structural steel	IS 2062	Fe 410-S
8	Hub	Cast Iron	IS 210	FG 200
9	Brake drum	Cast Iron	IS 210	FG 200
10	Cap	Cast Iron	IS 210	FG 200
		Mild Steel	IS 1079	-

3. **Software Used:** There are basically three software's were used in this paper.
- Autocad:** It is used for 2D sketches.
 - Catia:** It is used for 3D design.
 - Ansys:** It is used for finite element analysis.
4. **Trailer Component:** The major components of trailers are as follows:
- Chassis:** Chassis is the main component of trailer. Most of the trailer load should be carried by chassis therefore it is also called as carrying unit that is why design of chassis plays an important role in designing a chassis. It is the only part which can gives strength and stability to the trailer under different loading conditions. There are lots of things which are to be considered while designing chassis like strength of material, weight, selection of material and other properties of materials [12]. Earlier chassis is designed by using I section channel but now a day it is designed by using the C type channel. There are many C types of channel available in the market like 10"X3", 8"X3" and 6"X3". They all are used during fabrication of chassis as per application like 10"X3" C type channel used in balanced trailer and 8"X3" and 6"X3" both C type channel used in semi-trailer. Now a day's manufacturer using 8"X3" C type channel for making chassis because it provides more strength to the chassis compare to the 6"X3" C type channel. When the outer body of chassis is fabricated then we can connect the cross bearer in the middle part so that strength of chassis should be increased and the chances of chassis failure will be reduced. We have analyzed chassis with "C" type and "I" type cross bearer of 8"X3".

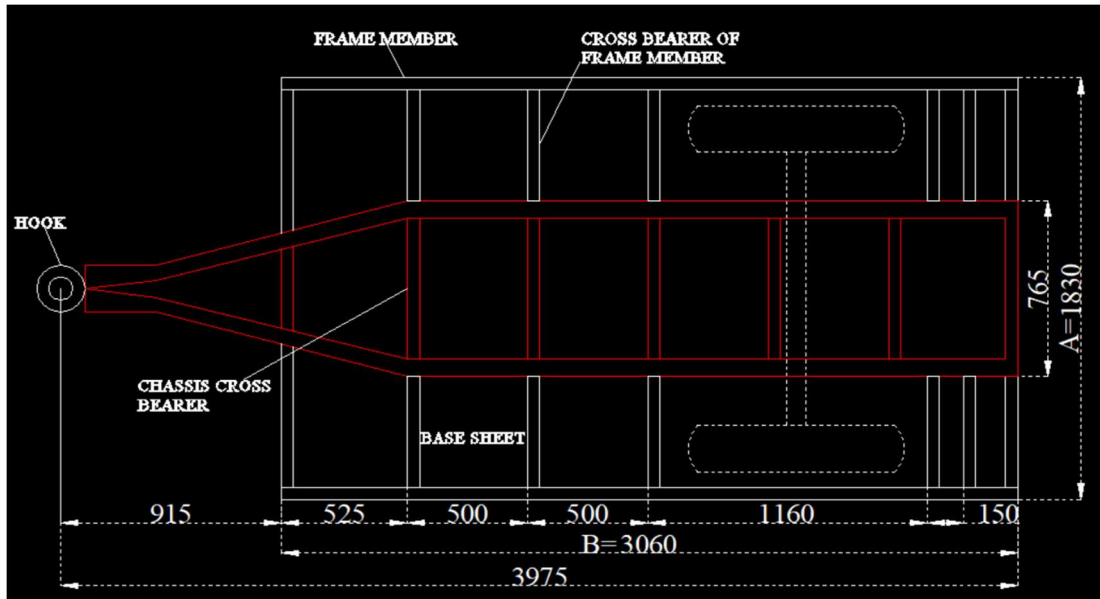


Fig 1 Base Structure Plan of Semi-Trailer

II. **Axle Assembly:** The axle is the major and important part of trailer. It supports all the static and dynamic load due to the road irregularities. Therefore it must be resistant to tolerate addition load and stresses [13]. The axle assemble should have following parts: axle, bearing, hub, wheel rim. The trailer should be designed as per the customer need such as with or without brake trolley. The basic difference in both the trolley is that brake trolley contains additional parts such as brake plate, brake drum, brake cam, brake pin, brake shoe compares to without break trolley as mention above [3]. The Fig 2 (a) and (b) shows the axle assembly with and without brake respectively. Therefore, axle assemble should be designed very carefully in keeping all this point. According to the Agricultural Tractor Trailer Specification (ATTS), the axle assemble is classified into two classes that is Class A and Class B. If the load carrying capacity of axle assembly up to 3 tonnes then it comes under Class A while the load carrying capacity of axle assembly up to 5 tonnes then it comes under Class B. The size of axle shaft is 63 square or 80 round for Class A and 75 square or 80 round for class B with applicable standard is IS 2062 [3].

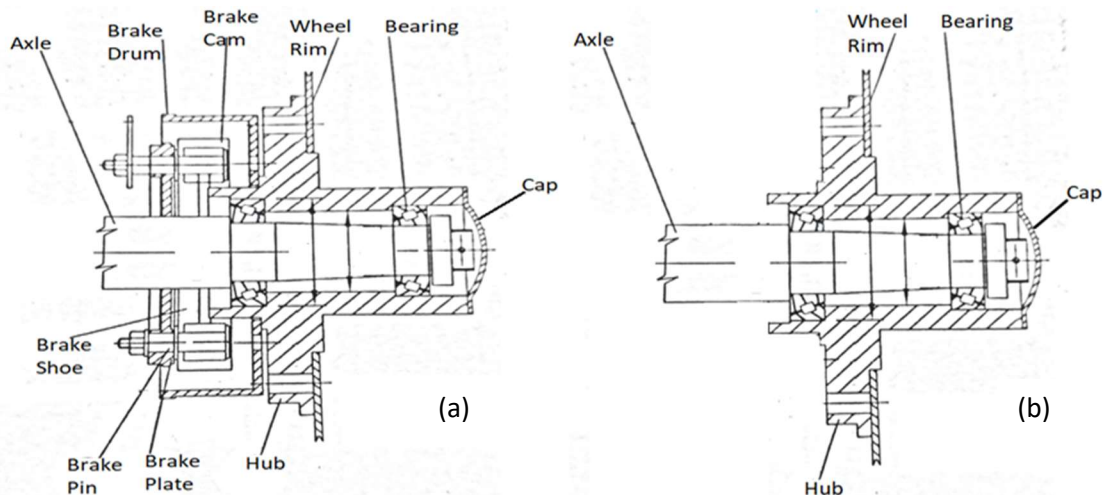


Fig 2 Axle Assemble with brake (a) without brake (b)

- III. **Frame member:** It is the main part of trailer. Some manufacturer is using only C type channel to fabricate frame of trolley while some of them are using both L type angle and C type channel in combination. As per review, we have found that some manufacturer used 1.5”X1.5” L type angle in bottom of the frame and 3”X1.5” C type channel in top of the frame while some of them used only 4”X2” C type frame in bottom as well as top of the frame. The strength and durability of 4”X2” C type channel frame is more than that of other frames. 6 mm sheet is used for making a base or platform of frame and 10-gauge (3.2 mm) sheet is used in sides of frame. Also 4”X2” C type channel is used in frame vertically for providing strength to the frame and some cross bearers are used in bottom of the frame to strengthen the frame horizontally.
- IV. **Spring:** The role of spring is very important while designing any vehicle because all the load of vehicle is carried by spring. The basic function of spring is to store energy and release the same slowly or rapidly depending upon the function of spring under consideration. Also, spring is also used to reduce shocks and jerks so that person sitting in the vehicle feels comfortable during the journey. There are many types of spring available in the market such as laminated or leaf spring, carriage spring, spiral spring and helical spring. They all are used as per the application in the automotive industry. Laminated spring is consisting of number of thin curved plates, each plate has same width and thickness but of different length. All plates are bent to the same radius of curvature. They are loaded at the end but supported in the middle. They are generally used in the trollies, heavy duty motor vehicle etc. [14]. Manufacturer is using 42” long, 38” long, 36” long types of leaf spring in the trollies as per capacity. Generally, 21 plates are used by the manufacturer in 42” long leaf spring.
- V. **Tyre:** Selection of tyre is very important for designing any vehicle. The selection of tyre size depends upon the trailer capacity. If the capacity of trailer is more than the size of tyre increases as well as cost is also increasing while if the capacity of trailer is low, then size of tyre is small. Therefore, firstly we have to decide the trailer capacity then on the basis of it we can select the tyre of trailer. Generally, 9.00 X 14 size used by manufacturer in trailer for capacity up to 5

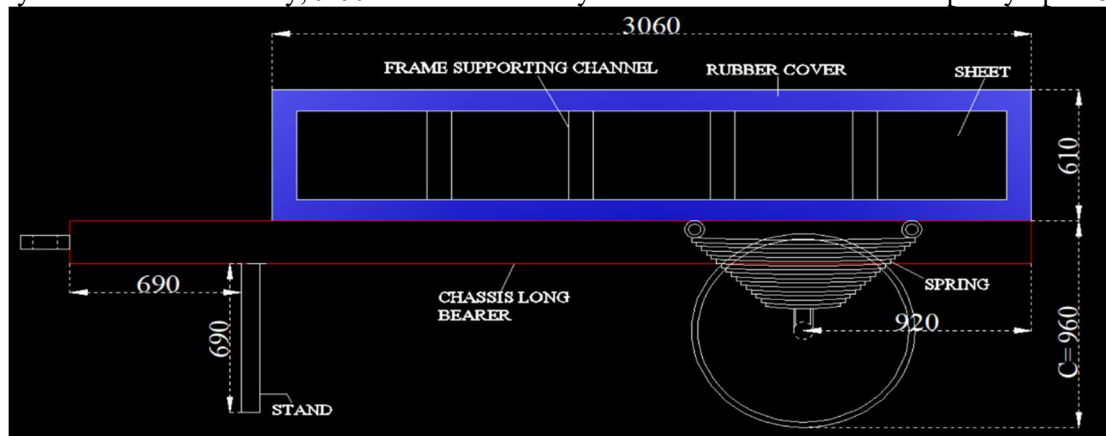


Fig 3 Elevation of Semi-Trailer

tonnes. 9.00 is representing the width of tyre in inches while 14 is representing the diameter of tyre rim in inches.

- VI. **Stand:** when the trailer is detached from tractor then for standing purpose, we can use stand. It's basically attached near front part of the chassis. Generally, two 75X75 C type channels welded together for fabricating a stand. Also, some manufacturer used 50X50 circular pipes but after detection from tractor the entire load should be carried by stand therefore for strength consideration, we have used 75X75 C type channel. The height of the stand is always less than

the height of trailer, with tyre inflated at the recommended pressure, when measured from the level supporting surface to the top of the platform.

- VII. **Hook or Tow Eye:** Tow eye is playing a role of intermediary between tractor and trailer. Basically, trailer is attached with tractor by tow eye. The movement of trailer is possible when the tractor is running. Therefore, design of tow eye is very important for designing trailer. During the running, if the design of tow eye is failed then trailer will be detached from tractor which causes road accident.

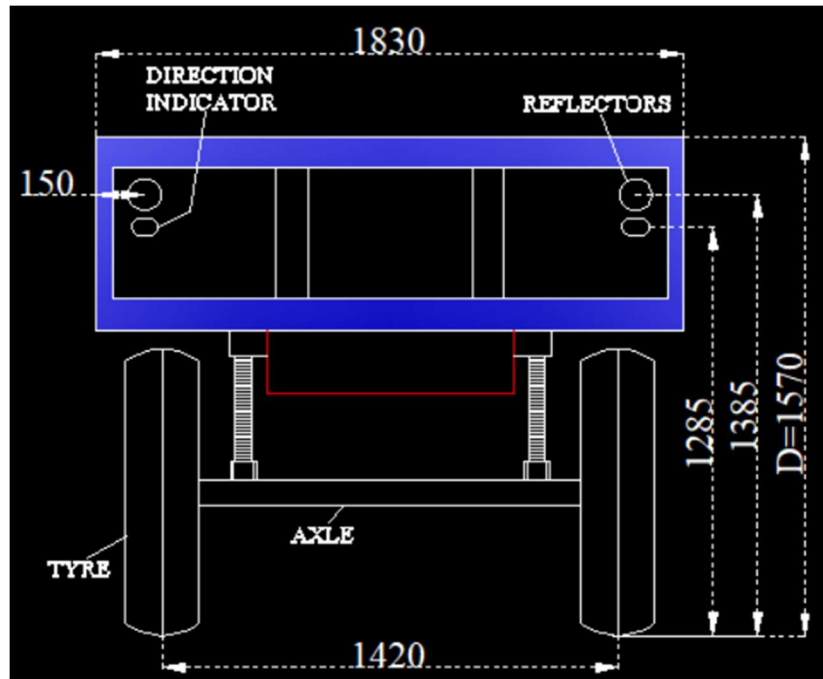


Fig 4 End Elevation of Semi-Trailer

5. **Dimension of Trailer:** After fabrication of trailer, we have to verified the design with the help of Indian Standard AGRICULTURAL TRACTOR TRAILER-SPECIFICATION (Third Revision). Either the design has made as per the standards or not. This verification should be done by the Chartered Engineer. Here we discuss the standards of the Semi-Trailer [3].

- I. The overall width (that is "A" as shown in Fig 1) of the semi-trailer between extreme point should not be greater than 2.5 m.
- II. The overall platform length (that is "B" as shown in Fig 1) of the semi-trailer between the extreme point should not be greater than 5 m.
- III. The height of semi-trailer (that is "C" as shown in Fig 3) measured from top of the platform to ground supporting surface should not be greater than 1.5 m.
- IV. The height of semi-trailer (that is "D" as shown in Fig 3) measured from top of the sideboard to ground supporting surface should not be greater than 2.2 m.
- V. The value of G in same-trailer can be calculated with the help of given formula

$$G = \frac{\frac{W \cdot B}{2} - R_t(H+B)}{(W - R_t)} \quad (1)$$

Where, W= Gross load of the trailer

R_t = Transfer of load to tow eye (in percent).

B = Overall platform length

H = Distance from center of tow eye to frame forward part of frame (H=915mm in Fig 1.)

If transfer of load from trailer to tow eye is 20 % then the above formula can be rewritten as

$$G = \frac{(3B-2H)}{8} \quad (2)$$

VI. The ground clearance of semi-trailer should not be less than 300 mm.

6. **Lighting Requirement:** Two white color reflectors and two red color reflectors have been fitted at front side and rear side respectively in semi-trailer. They are fitted at a distance not more than 150 mm from extreme end of trailer to Centre of reflector. The round shape reflector has been used with reflecting area not less than 3000 mm². The rear reflectors used as a tail lamp in semi-trailer and fitted at a distance more than 350mm and less than 1600 mm. A semi-trailer also has two direction indicators also known as turn indicators. It flashes 60-120 flash per minute. They are mounted at a height more than 1000 mm but less than 1500 mm. The illuminating area of turn indicator should not be less than 2250 mm². The direction indicator and reflector are shown in fig 4.
7. **Modeling and Analysis of the chassis in ANSYS:** Fig 5 shows the different views of the chassis prepared in the Catia V5 software, which is further saved in the IGS format to do the further analysis in ANSYS.

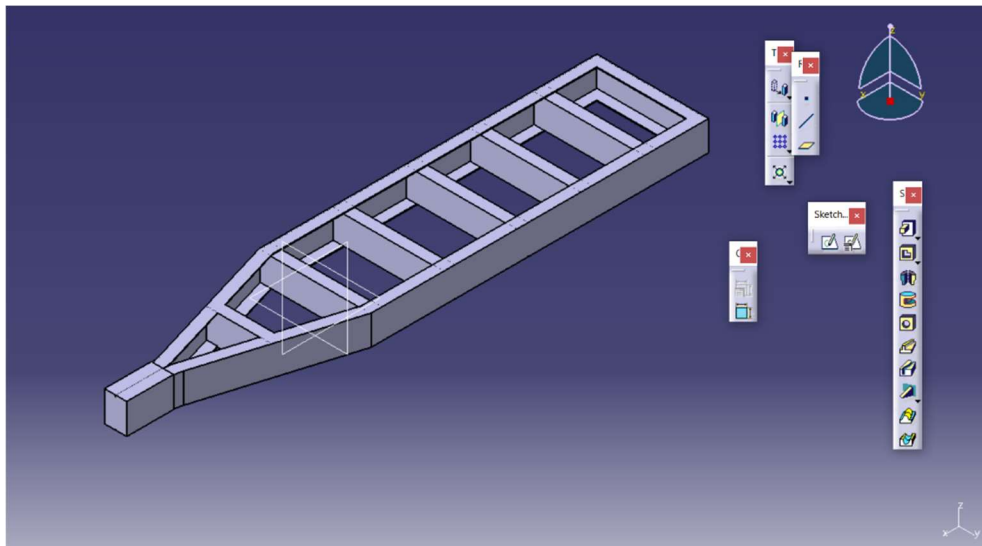


Fig 5 Isometric view of the chassis

Analysis of the chassis is done considering the chassis (ignoring the design of the hook, cause the reaction force in front of the chassis portion) in the static loaded condition, chassis material is of mild steel IS 2062.

Fig 6 shows the loading condition on the chassis (with “C” section cross bearer and “I” section cross bearer) caused due to load induced by 3.5 tones of load and due to the weight of the frame which will generate the force uniformly of magnitude= 41.964 KN in the sections shown red in color.

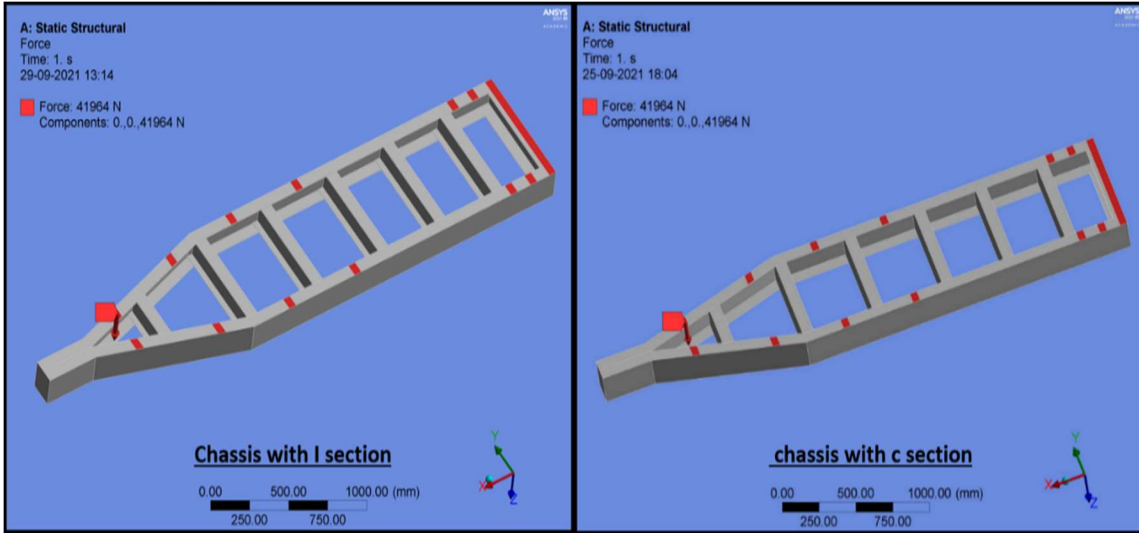


Fig 6 Loading condition

Fig 7 shows the equivalent (von-mises) stress developed in the chassis member (with “C” section cross bearer and “I” section cross bearer) due to the 3.5 tonnes of the load plus the load caused due to the weight of the frame. Red color shows the maximum magnitude of stress whereas blue region specifies the low magnitude of stress.

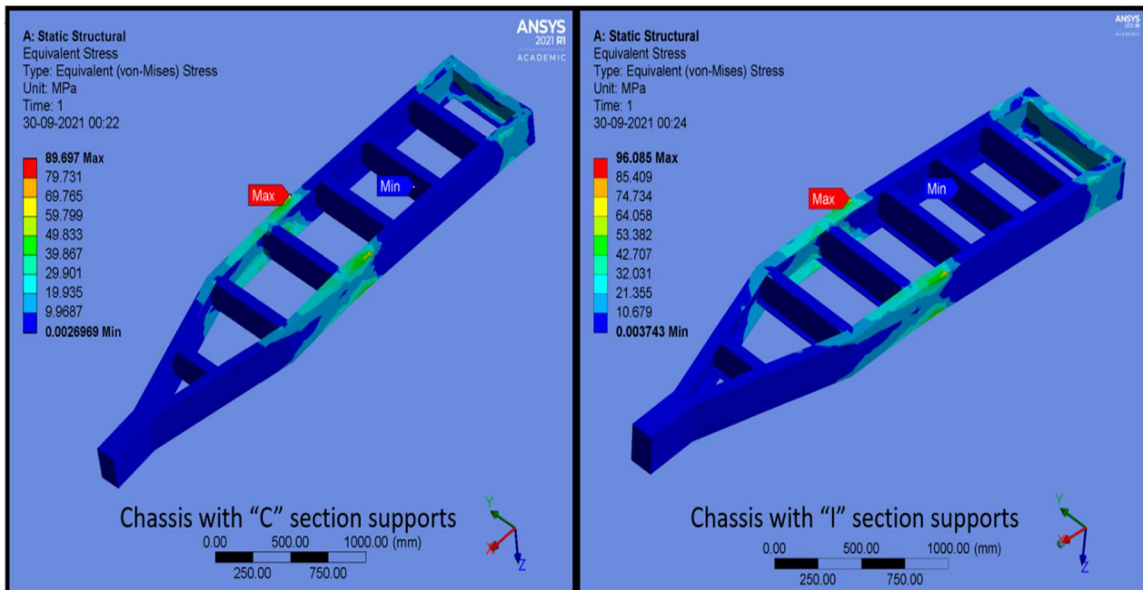


Fig 7 Equivalent (von-mises) stress analysis in trailer chassis

Fig 8 shows the equivalent elastic strain induced the chassis (with “C” section cross bearer and “I” section cross bearer) due to the loading condition. Red region shows the maximum strain and the blue region shows the minimum strain magnitude.

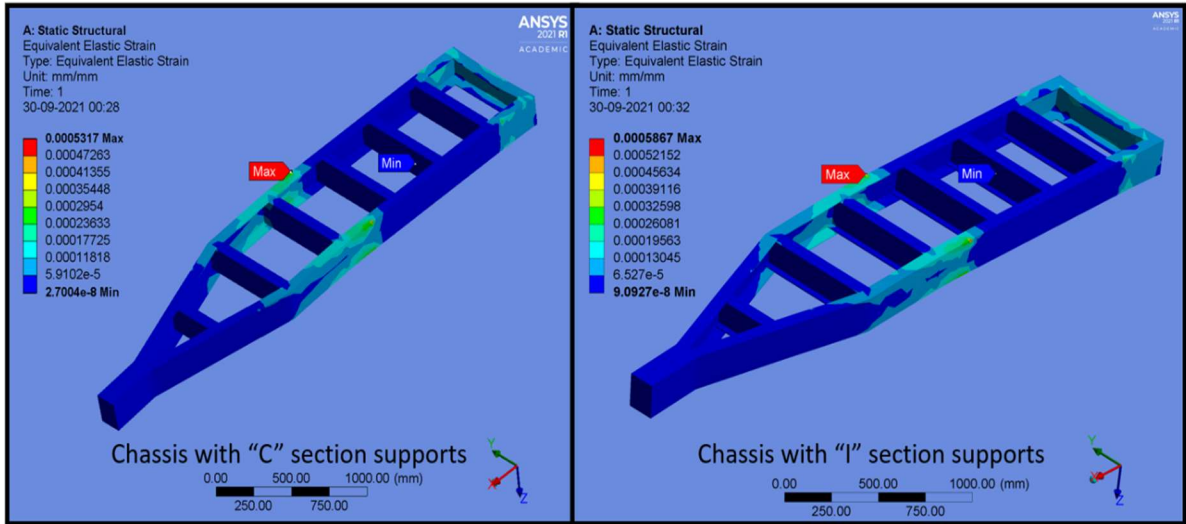


Fig 8 Equivalent elastic strain analysis in trailer chassis

Fig 9 shows the total deformation caused in the chassis (with “C” section cross bearer and “I” section cross bearer) due the load/stress. Red region shows the maximum deformation and the blue region shows the minimum deformation.

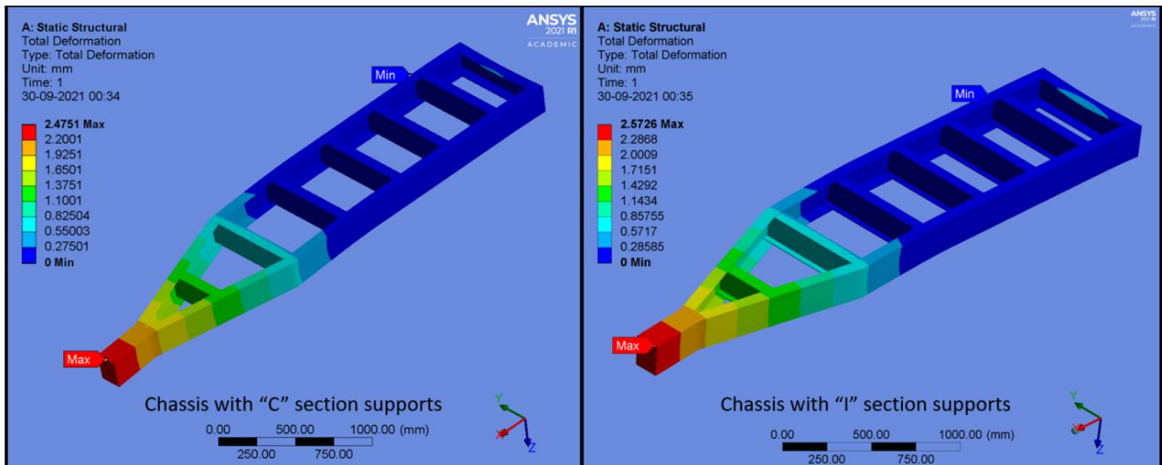


Fig 9 Total deformation in chassis

8. **Result and Discussion:** Chassis is the main component of trailer. Most of the trailer load should be carried by chassis therefore it is also called as carrying unit that is why design of chassis plays an important role in designing a chassis. It is the only part which can gives strength and stability to the trailer under different loading conditions. There are lots of things which are to be considered while designing chassis like strength of material, weight, selection of material and other properties of materials. In this paper, complete design of trailer was discussed also analysis of chassis with C type section and I type section cross bearer was performed and then result of each analysis was compared. After comparison it was found that the equivalent stress and strain generated in chassis with C type section cross bearer is lower than I type section cross bearer. Also, total deformation in C type section cross bearer is lower than that of I type section which means that strength of C type channel cross bearer is more than that of I type section. Therefore, it is suggested that

manufacture should always be used a C type section cross bearer in manufacturing of chassis compared to I type section cross bearer.

Table 2 Result of Chassis with C type and I type Section.

Sr. no.	factors	Values corresponds to C section	Values corresponds to I section
1.	Equivalent Stress	89.697 MPa	96.085 MPa
2.	Equivalent Strain	5.317×10^{-4} mm/mm	5.867×10^{-4} mm/mm
3.	Total deformation	2.4751 mm	2.5726 mm

- 9. Conclusion:** The movement of goods from one place to another place is possible by using trailer because its very cost-effective mode of transportation. Trailer is mostly used for agricultural purposes. After doing the literature survey it was found that there is no such paper available who can disclose complete design of trailer. Therefore, complete design of 3.5 tonne agricultural semi-trailer is designed and all the compliances has been made as per the Industrial Motor vehicle rule IMVR 1989. Also, analysis of chassis with C type section and I type section cross bearer was performed and it was observed that C type section cross bearer has given better result than I type section cross bearer as shown in table 2. This paper can be used by the local MSME manufacturer to comply the guidelines in their practice by fabricating this trailer.

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