Design and Analysis of Dump Truck Floor Bed

Ramacharan C[1] Dr. A S Prashanth[2]
[1]PG Student [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]Dr. Ambedkar Institute of Technology, Bengaluru.

Abstract— Construction of the truck floor bed is usually made up of prismatic beams. Currently in this article concept of the beams of uniform strength is used to avoid the concentration of high stress at critical points. The strength of beam mainly depends on cross section and the bending moment along the span. Highest stress value found in the critical sections mostly in the supports and in all other sections, the stress is well below the permissible limit, which means that the material potential capacity to carry load is not fully utilized. Hence, 'I' section is used for obtaining higher moment of inertia and also in order to enhance the load carrying capacity the variable cross section beams is used to resist the corresponding bending moment. The floor bed with payload capacity of 20 tonnes is used in the current study and also it is subjected to off design impact load using finite element method. The usage of beams of uniform strength have given better results and also optimised the total weight giving the same load carrying capacity. Any additional weight in truck reduces the efficiency and increases fuel consumption which leads to carbon footprint and adaptation of this technique in present work proved to be cost effective upon implementing in mass production.

Key words: Dump Truck, FEM, Floor bed, Beams of uniform strength, Linear static analysis, off design impact analysis

I. Introduction

Transportation plays a significant role in growth of the country's economy, so there is need of the optimum design of the trailers. Majority of the truck bodies and trailers construction companies in India are semi organised or unorganised, which don't have the optimum design.

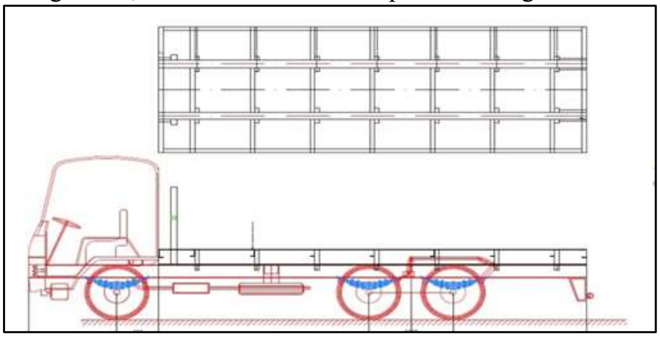

Fig. 1: Basic Layout of the Truck Floor Bed

Every extra weight the truck carries increases the manufacturing cost, lower fuel efficiency and reduces vehicular pay load capacity. Simulation is an important method to find the optimum design with lesser cost and time.

II. Objective

- Design of truck floor bed for 20 tonnes payload capacity using I- cross section and beams of uniform strength.
- Design checks like static analysis and off design impact analysis are to be carried out
- Weight optimization and selection of the material for manufacturing.

III. Scope of Work

The concept, beams of uniform strength is used, which aims to reduce the weight of the floor bed by reducing the kerb weight of the truck and increasing the payload capacity. Fuel inefficiency of the truck will also be increased. which will reduce the carbon dioxide and NOx emissions. These methods can contribute to reduce green house effects and hence the global warming.

IV. Material Selection

Standard structural steel (IS 2026) is extensively used in dump truck floor bed. Structural steel is used in beams. It is cost effective and easily available.

HARDOX 450 is used in floor bed sheets, which highly abrasion resistant sheet. It has good cold bending properties and good weld ability. The material is quenched to obtain desirable mechanical properties.

V. Analytical Calculation

A. Design calculation of the I beam:

Payload of the truck = 20 tonnes
Number of the beams in floor = 6

So load on each beam $= \frac{20000\times9.81}{6}$

$= 32700$ N

UDL load on each beam $= \frac{32700}{5000}$

$= 6.54$ N/mm

Floor bed cross beams are simply supported beams with overhang loads.

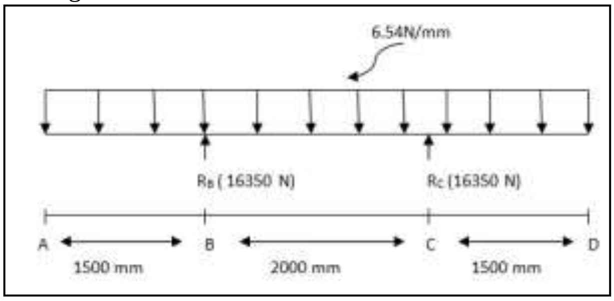

Fig. 2: Free Body Diagram Of Beam

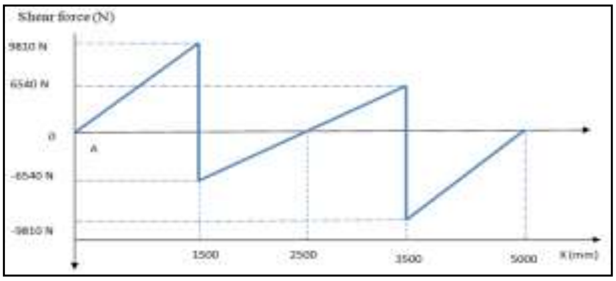

Fig. 3: Shear Force Diagram (SFD)

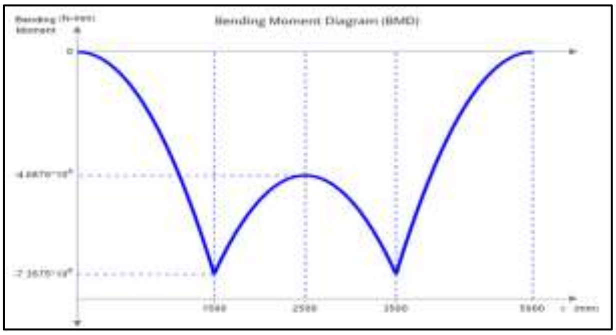

Fig. 4: Bending Moment Diagram (BMD).

B. Calculation of the Bending Stress:

Maximum Bending stress, $\sigma_b = \frac{M}{I} \times y$ ...... (5.1)

$= 148.3132$ MPa

Allowable stress is for this design $= \frac{\sigma y}{FOS}$ ...... (5.2)

$= 250/1.5$

$= 166.66$ MPa

C. Calculations for Beam of Uniform Strength:

The standard dimension S100×11.5, taken from American Standard Shape [6]. Keeping the flange width, flange thickness and web thickness same, height of the web is varied to get beams of uniform strength.

Moment of inertia of beam calculation done using parallel axis theorem.

$$I_{XX} = I_1 + A_1 \times y_1^2 + I_2 + A_2 \times y_2^2 + I_3 + A_3 \times y_3^2 \text{ .... (5.3)}$$

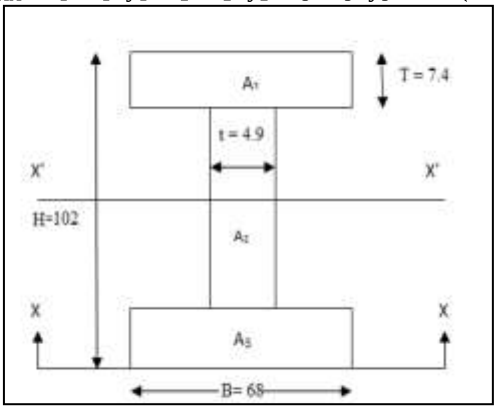

Fig. 5: Cross Section of the I Beam

Moment of inertia of rectangle shape

$$I = \frac{BH^3}{12} \text{ mm}^4 \text{ .... (5.4)}$$

As H is variable, quadratic equation is obtained substituting in bending equation. By formulation following equation, a polynomial curve is obtained by considering simply supported part i.e. distance between the supports. Quadratic equation for web height is

$$y = 9E\text{-}05x^2 - 3E\text{-}17x + 62 \text{ ...... (5.5)}$$

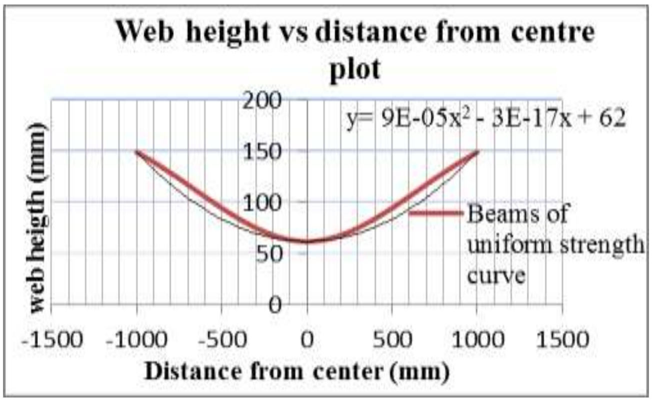

Fig. 6: Graph Showing Variation of Height Form Centre of Beam

VI. Geometric Configuration

The geometric model of the truck floor bed is done using CAD tool. Base line model is made of the I- section and have 105 components. modified model made of the beams of the constant strength and contains 95 components.

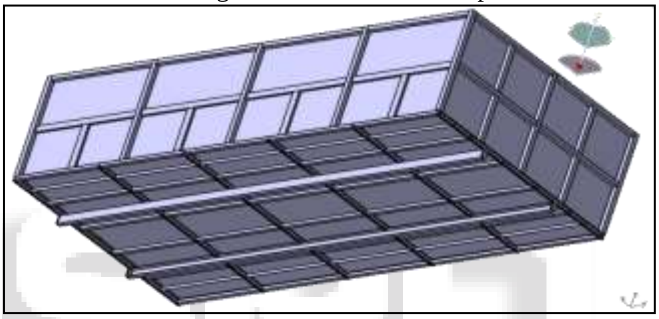

Fig. 7: Floor Bed of the Base Line Model

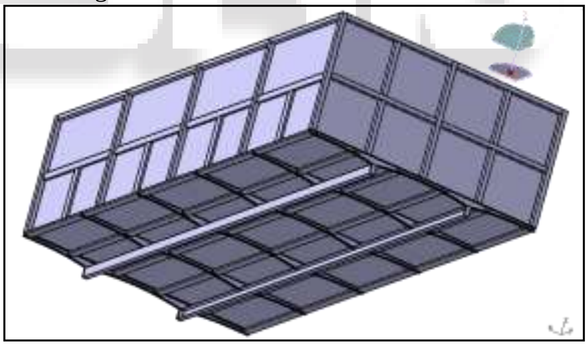

Figure 8: Floor Bed of the Modified Model

Fig. 9: I- Beam of the Base Line Model

Fig. 10: Beam of Constant Strength of Modified Model

VII. STATIC STRESS ANALYSIS

A. Boundary Condition:

Remote force: The payload of 20 tonnes i.e. 196200N is applied in the form of remote force by creating the remote point at [2500, 5000, 1250].Centre of gravity is assumed to be at the centre of the trailer in the full load condition.

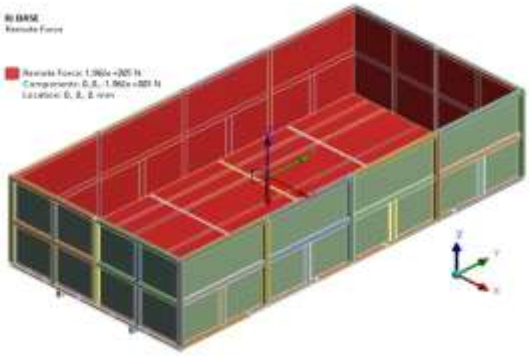

Fig. 11: Remote Force Acting At CG of Trailer on All Load Bearing Surface, In the Down Ward Direction

Fixed Support: The floor bed is mounted on the sub-frame, which is mounted on the chassis using splice joint. CAD Model contain two long members of the sub-frame, which are fixed.

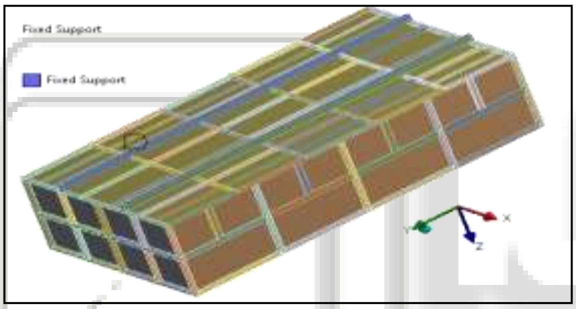

Fig. 12: Fixed Support In The Lower Side Of The Floor Bed.

B. Results of Static Analysis

Von-Mises Stress Obtained For Base Line Model Is 36.475mpa

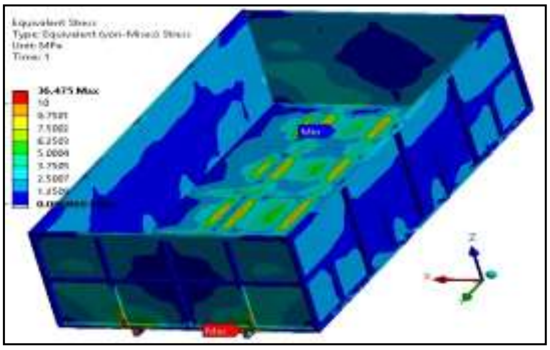

Fig. 13: Von-Mises Stress Result Of Base Line Model

Total Deformation Obtained During The Static Analysis Of Base Line Model Is 0.81451 Mm.

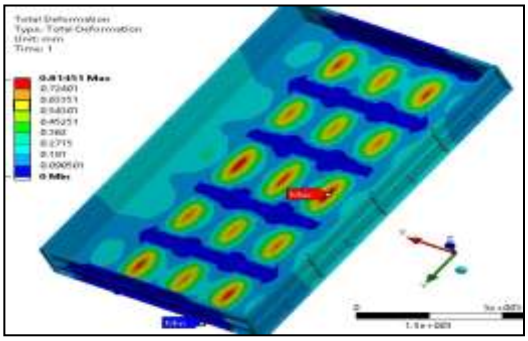

Fig. 14: Total Deformation Of Baseline Model

Von-Mises Stress Obtained For Modified Model Is 74.95 Mpa

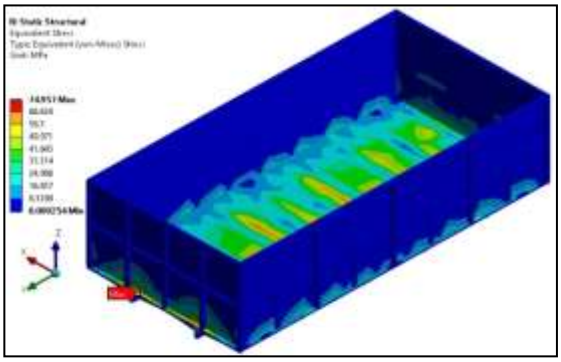

Fig. 15: Von-Mises Stress Result of Modified Model

Total deformation obtained during the static analysis of modified model is 0.049 mm

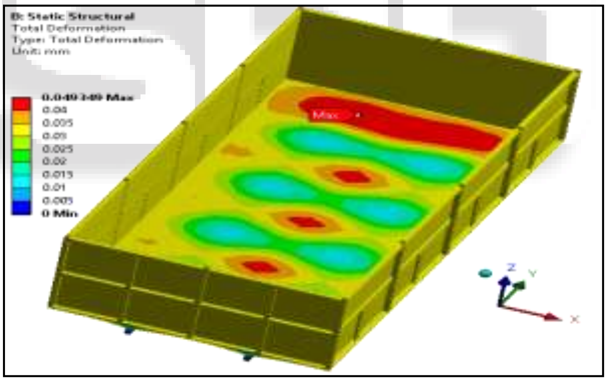

Fig. 16: Total Deformation of Modified Model

VIII. IMPACT ANALYSIS

Stone of 4 tonnes of spherical shape is dropped from the height of 2.5m with the velocity of 7.003m/s.

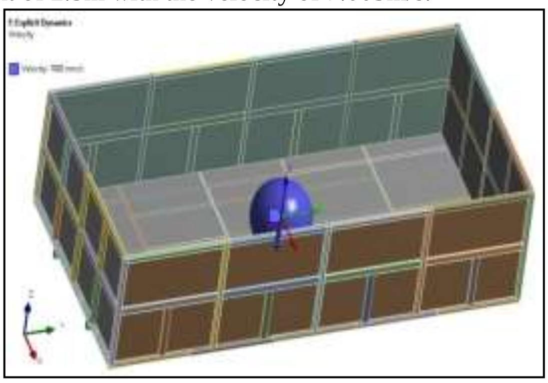

Fig. 17: Simulation of Stone Falling On the Floor Bed

A. Base Line Model:

Maximum von-mises stress is 655.49MPa which is below the yield stress 1200 MPa. So floor can withstand impact of the 4 tonnes weight from height of 2.5m.

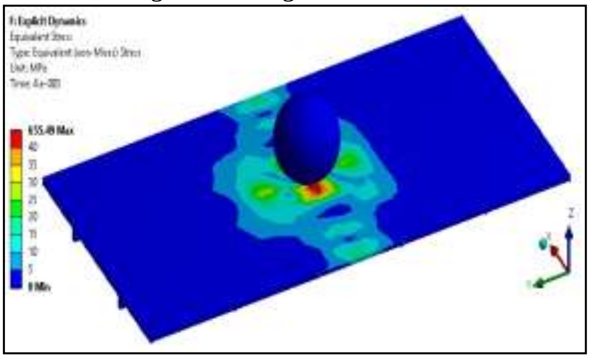

Fig. 18: Von-Mises Stress of Off Design Condition, Impact Analysis for Base Line Model on Floor Bed

The total deformation off design condition result shows the stone, which is falling on the floor bed has the highest deformation i.e. 27.864mm, Which is found in the stone itself. and maximum deformation in floor bed is 7.5mm

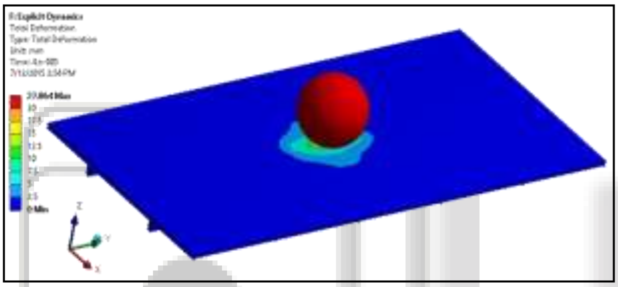

Fig. 19: Deformation Of Off Design Condition, Impact Analysis for Base Line Model

B. Modified Model:

Von-mises stress is found in floor bed sheet 521.91 MPa.

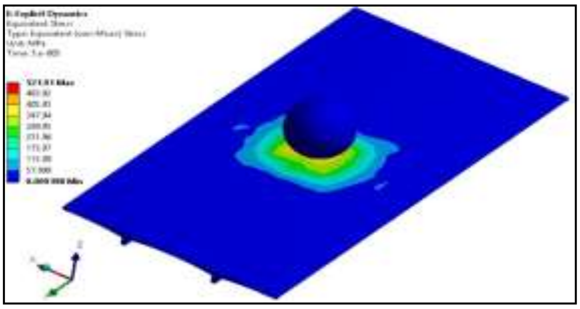

Fig. 20: Von-mises stress contour of off design condition, impact analysis for modified model on floor bed

The total deformation off design condition result shows the stone, which is falling on the floor bed has the highest deformation i.e. 34.95mm and maximum deformation in floor bed is 4.3751mm.

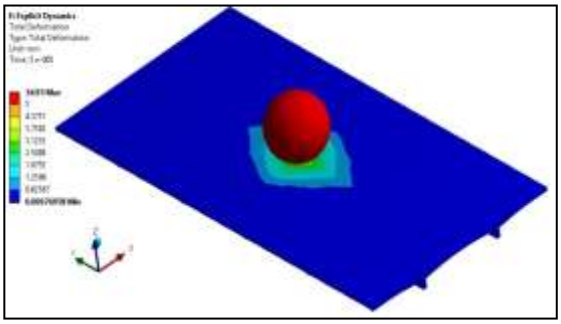

Fig. 21: Total deformation of off design condition, showing stone has maximum deformation.

IX. RESULTS

A. Static Analysis Result

Model	Weight of structure (kg)	Von-mises Stress (MPa)	Total Deformation (mm)
Base line	7916.4	36.475	0.8145
Modified	7836 kg	74.957	0.049

Table 1: Results of static analysis

The maximum stress is found in supports of beam which is made structural steel (IS 2026) having yield strength of 250MPa. Results obtained are below allowable stress 166.66MPa. Hence the design is safe with a weight reduction of 203kg.

B. Off design Impact Analysis:

Model	Von-mises Stress(MPa)	Total Deformation(mm)
Baseline model	655.49	7.51
Modified model	521.91	4.37

Table 2: Results of off design Impact analysis

The maximum stress is found in the floor sheet, which is made up of the HARDOX450 having the yield strength of the 1200MPa. Results obtained are below the yield strength. hence the design is safe.

C. Optimization of Floor Bed:

Component	Base Line Model	Modified Model	Difference In Mass kg	Quantity	Total Mass Kg
	Mass in Kg	Mass in Kg			
Horizontal beams	56.272	54.54	1.732	6	10.392
Stiffeners	23.213	20.741	2.472	30	74.16
L Angle	11.85	-	11.85	10	118.5
Total weight reduced					203.05

Table 3: Weight Optimization in Different Components of Floor Bed.

Weight of base line model is 7867.8 kg and modified model weighs 7664.75 kg. Therefore reduction in weight is 203.05 kg.

X. CONCLUSION

Extensive use of the C-Section beam in the floor bed can be replaced by the I-Section beam as it has the high area moment of inertia for same area. Even prismatic I-beam do not utilize material potential for fullest, as stresses are not uniformly distributed along the length of the beam. So these prismatic beams are replaced by beams of uniform strength. Use of the beams of uniform strength showed drastic reduction in the deflection value and show uniform stress distribution comparatively with stresses being well within the allowable limits for the static analysis. In off design impact analysis, modern high strength material HARDOX 450 is selected as its properties meet the requirement. Results showed von-mises stress of 750 MPa, which is below yield stress of the material which is 1200MPa. Deformation is high as impact area is too small . Results obtained are satisfactory. Use of the beams of uniform strength instead of prismatic beam reduced the total beam weight 10.39 kg. By hit and trail method the weight in other parts are reduced by 203.05kg in total. The main objective of weight reduction is done using beams of uniform strength on prismatic I- section beam by 10.39 kg and on whole structure 203.05kg. This increases the payload capacity and reduce fuel consumption.

XI. SCOPE FOR FUTURE WORK

Prismatic beams can be replaced by beams of uniform strength, since these have stress distributed along the length. The customer is more benefited in terms of durability and extra payload. The use material with high strength to weight ratio enhances the performance and optimisation is flexible in different components of the floor structure.

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