

Design and Analysis of Armored Vehicle Launched Bridge (AVLB) for Static Loads

Ms. Chaithanya Kalangi¹ Yugandar Sidagam²

¹Associate Professor ²M.Tech Student

^{1,2}Department of Mechanical Engineering

^{1,2}Marri Laxman Reddy Institute of Technology and Management, Dundigal, Hyderabad (TS), India

Abstract— The Armored vehicle launched bridge (AVLB) is an assault bridge employed during battles. The existing AVLB has capacity of 70 tonnes. However a need was identified to increase its Load bearing capacity above 90 tonnes along with higher factor of safety while engaged in military operations. This report presents the improved design of AVLB. The 'I'-Sections installed in design promotes high moment of inertia and stiffness which makes it resistant to bending moment. The web of 'I'-Sections provides resistance against shear force. The 3D Model of AVLB created in Solid works. And finite element analysis was performed on the model of AVLB to identify the highly stressed components of design for MLC 90 & MLC 100 static structural loads. The Modal analysis using Finite Element Method (FEM) is used to determine mode shapes and this has been accomplished by the commercial finite elements package ANSYS. And all the efforts made to ameliorate the original AVLB to suit for MLC of 90 and 100 tonnes, along with additional safety to AVLB design by considering the factor of safety value greater than 2 and above.

Key words: AVLB (Armored vehicle launched bridge), Assault Bridge, FEA (Finite Element Analysis), MLC (Military Load Classification), Von Mises

I. INTRODUCTION

In response to the demanding war scenarios designers and manufacturers have developed many new technologies for their vehicles. This technology has helped to improve their lethality and survivability, as well as increase the level of protection for the soldiers. However, this new technology has also resulted in an increase in weight. This increase in weight may have an adverse effect on its ability to defeat natural and man-made obstacles.

Gaps are one of these obstacles. The Army has various gap defeat equipment to defeat various mission, including assault and line of communication. One of the gap defeat equipment is the Armored Vehicle Launched Bridge (AVLB), an assault bridge in service since the 1960s. The Armored Vehicle Launched Bridge (AVLB) is a folding bridge carried by a tank chassis. Both the M70A1 tank and M48A5 tank chassis have been used as the carrier. Upgrades to the bridge have increased its carrying capacity from a Military Load Class MLC-60 to MLC-70. Test results for the bridge have shown greater load carrying capacity than its load rating. Because of this, interest has been shown in increasing the load rating of the bridge without making any further design changes to the bridge. While increasing the rating of the bridge is desired, it may have an adverse effect on its durable life [1].

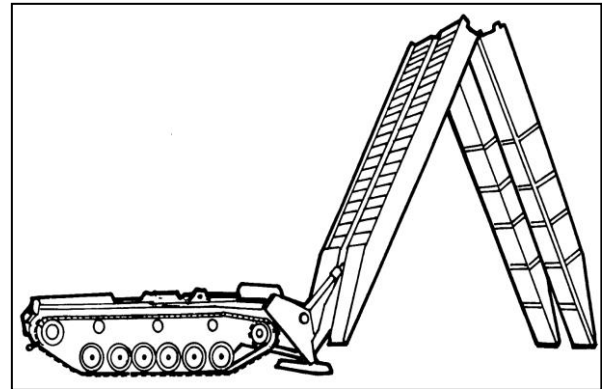


Fig. 1: A Sample of AVLB

II. WORKING OF AVLB

The AVLB's job is to allow Armored or infantry units to cross craters, anti-tank ditches, blown bridges, railroad cuts, canals, rivers and ravines, when a river too deep for vehicles to wade through is reached, and no bridge is conveniently located (or sufficiently sturdy, a substantial concern when moving 70-ton tanks).

The Armored Vehicle Launched Bridge was designed to launch and retrieve a class 70 bridge. The AVLB vehicle carries a crew of two. The AVLB consists of three major sections: the launcher, the hull, and the bridge. The launcher is mounted as an integral part of the chassis. The bridge, when emplaced, is capable of supporting tracked and wheeled vehicles with a loading capacity up to 70 tons.

The bridge layer unfolds and launches its cargo, providing a ready-made bridge across the obstacle in only minutes. Once the span has been put in place, the AVLB vehicle detaches from the bridge, and moves aside to allow traffic to pass. Once all of the vehicles have crossed, it crosses the bridge itself and reattaches to the bridge on the other side. It then retracts the span ready to move off again. AVLBs can carry bridges of 70 feet (19 meters) or greater in length.

The dynamic loading of AVLBs is quite different from typical civilian bridges and is usually characterized by very high stress/low cycle type of loading accompanied by large deflections. Furthermore, several AVLBs have been found to fail in the field under high stress fatigue. Therefore, the dynamic behavior of these bridges is essential in understanding the failure mechanisms and improves their overall design [2]. This new and advanced technology is designed to eliminate uncontrolled variables in testing environment, such as experimental induced errors associated with changes in boundary conditions, environmental conditions and battle field situations.



Fig. 2: Working of AVLB

III. LITERATURE REVIEW

A. Bernard Sia

[1] has performed analysis to predict the fatigue life of the Armored Vehicle Launched Bridge (AVLB) for Military Load Class (MLC) 70 and 80 loads. Fatigue life was estimated using stress-life, strain-life, and fracture mechanics approaches. The analysis was focused on 4 different components, as these components showed the highest stress magnitude during MLC 70 testing. The stress-life approach provided the most conservative estimate of fatigue life.

B. Samer Petro, Shen-En Chen, Suhas Venkatappa, and Hota Ganga Rao

[2] published a paper on The Dynamic Behavior of an Armored Vehicle Launched Bridge, the abstract of the paper reports the Forced vibration tests using shaker excitation were used to excite the vertical bending modes of the AVLB while 120 accelerometers were used to measure the bridge response in the vertical direction. The results indicate that the bridges' four girders behave like lightly damped and coupled girders that exhibit complex vibration modes. An additional modal test was also conducted to study the dynamic behavior of the AVLB with one of the pins, from one of the girders removed. The results from this test show significant stress redistribution and a different dynamic behavior. This paper also reports AVLB testing under both simply supported conditions and free-free conditions. The results were also compared to finite element testing results.

C. Jeong-Hoon Choi

[3] has published a paper on The Fracture Analysis and Remaining Life Estimation of the AVLB Sub Components, the paper reports the experimental results from both fracture mechanic approach and AE monitoring provide essential information to understand the fatigue crack growth in the critical components. Linear Elastic Fracture Mechanics (LEFM) is applied in the FEM analysis to obtain the stress intensity factor. From the experimental and numerical results, the critical crack length and the remaining life of the critical AVLB components are estimated to help establish the damage assessment for the AVLB.

D. Dnyaneshwar J. Sushir, Prashant N. Ulhe

[4] published a paper on Failure Analysis of Centre Pin Joint Used in Heavy Assault Bridge this paper reports the failure analysis of the centre pin joint used in heavy assault bridge by modifying the design and increasing its load carrying capacity. As previously centre pin joint is replaced by modified pin joint, its load carrying capacity is enhanced by using FEA.

E. Wieslaw Krason, Jerzy Malachowski

[5] published a paper on Experimental and Numerical Studies of the Scissors-AVLB Type Bridge. Scissor bridges are characterized by high mobility and modular structure. Single module-span consists of two spanning parts of the bridge; two main trucks and support structure. Pin joints are used between modules of the single bridge span. Numerical analyses here presented were carried out for a scissors-type BLG bridge with tread ways extended as compared to the classical bridge operated.

The BLG Bridge was numerically analysed to assess displacements and distributions of stresses throughout the bridge structure in different loading modes. Verification of the reliability of models was performed by comparing deflections obtained in the different load modes that corresponded with tests performed on the test stand. It has been shown that the examined changes in conditions of loading the tread ways of the bridge are of the greatest effect to the effort of the area of the joint which is attached to the girder bottom. Stress concentrations determined in the analysis are not hazardous to safe operation of the structure.

F. Mike Laviolette

[6] published a paper on Bridge Construction Practices Using Incremental Launching. Bridge construction over deep valleys, water crossings with steep slopes, or environmentally protected regions can offer many challenges. The incremental launching method (ILM) for bridge construction may offer advantages over conventional construction, including creating minimal disturbance to surroundings, providing a more concentrated work area for super structure assembly, and possibly increased worker safety given the improved erection environment.

The ILM involves assembly of the bridge superstructure on one side of an obstacle to be crossed, and then movement (or launching) of the superstructure longitudinally into its final position. The objective of the work summarized in this report was to provide bridge owners, designers, and contractors with information about the ILM, including applications, limitations and benefits.

G. Stephen J. Ressler and Celal N. Kostem

[7] published a report that describes An Analysis of the U. S. Army Light Vehicle / Foot Bridge Design (LV/FB), a light weight tactical bridging system. The LV /FB are a modular space frame constructed of aluminum alloy tubing. The deck of the bridge is a flexible composite membrane, composed of Kevlar- 49 and E-glass fibers embedded in a neoprene matrix. The first phase is an investigation of the behavior of the composite membrane deck. Nonlinear and linear finite element analyses are used.

The principal objective is to determine how the behavior of the membrane is affected by the orientation of Kevlar-49 and E-glass fibers. The second phase is an investigation of the global behavior of the entire structure subjected to MLC 7 design loads. Nonlinear and linear finite element analyses are used to determine maximum stresses and deflections in critical structural members. The intended load capacity of the structure is Military Load Class 7 (MLC 7) but the actual capacity of the structure is estimated to be approximately MLC 5.

H. J. B. Kosmatka

[8] published a paper on Dynamic Behavior of the Composite Army Bridge (CAB): The U.S. Army and DARPA have developed a short-span advanced composite 14-meter bridge for crossing MLC-100 (100-ton) tracked and wheeled vehicles across 12-meter gaps. The Composite Army Bridge (CAB) is a technology demonstrator that is primarily fabricated using carbon/epoxy along with the Vacuum Assisted Resin Transfer Molding (VARTM) manufacturing method. It is observed that heavy vehicles moving quickly on these lightweight bridges can lead to large dynamic responses (bouncing) and load factors. Potential damage to the carbon fibers, epoxy resin, bonded joints, and bolted joints are of concern. A field test was performed to assess the long term dynamic performance of the bridge subjected to three different vehicle types: (a) a tracked M1-A1 (MLC-70) tank, (b) a wheeled 100-ton Heavy Equipment Transporter (HET), and (c) a tracked M88 towing an M1-A1 tank. Over 2000 crossings were performed at different speeds and bank conditions. Dynamic load factors of 1.5 were measured for many crossing speeds. Load factors approaching 1.66 were observed during low-speed panic braking stops due to the increased loading on the forward axles and reduced loading on the rear axles. Thus, advanced composites (carbon/epoxy) have been proven as a high-performance alternative to conventional metallic materials for mobile bridging.

I. Hornbeck, B., Connor, R., Kluck, J

[9] published a paper on Trilateral Design and Test Code for Military Bridging and Gap-Crossing Equipment. The paper conveys that Code covers loading, design, and testing requirements to be used for the development of military Clear-span bridges, piers, floating bridges, rafts, equipment causeways, and erecting and launching structures that are part of the equipment. The Code is used to confirm that equipment will meet the performance specified by the user. The requirements of this Code are to be regarded as the minimum acceptable standards of performance.

Bridging and gap crossing equipment will be designed to meet the user's requirement by applying the

necessary loading conditions, design parameters, and testing given in this Code. The Code lists material properties required and also gives design data for guidance and checking, but the criteria are that the equipment pass the requisite tests, meet the user's requirement, and can be manufactured readily.

J. D.V.Srividya, B.Raju and D.Kondayya

[10] published a paper on Design Optimization of Armored Vehicle Launched Bridge for Structural Loads. The paper conveys the initial design of the original model for 70 tons. To accomplish the 10 ton increase of the AVLB finite element analysis was performed on the original model of 70tons AVLB to identify the highly stressed components and the highly stresses components have redesigned and upgraded to a new class 80AVLB.And also reports the dynamic behavior and investigates into the vibration characteristics of the AVLB including the natural frequencies and mode shapes.

IV. CAD MODELLING OF AVLB

The 3D Model of AVLB was generated by using a 2D drawing. Initially all components of AVLB are generated in a Solid works (version 2014) separately and later all of them were assembled together. To perform analysis on AVLB model the CAD file of Solid Works was exported in .IGS Format.

A. Design Specifications AVLB Bridge

Weight of the Bridge	=	3.56 tonnes
Overall Length of the Bridge	=	~30 Feet
Half Length of the Bridge	=	~15 Feet
Width of the Bridge	=	~8 Feet
Width of Track	=	~3 Feet
Height of the Bridge	=	~1 Feet
Pay Load Capacity	=	90 to 100 tonnes
Type of Bridge	=	1× scissors-type folding bridge

I-Sections were installed in design of AVLB to achieve high moment of Inertia, Stiffness to overcome bending moment and resistance to Shear Force.

B. Specifications of I-Section used in AVLB

Flange Dimensions of I-section		
Width w_f	=	228.600 mm
Thickness t_f	=	25.400 mm
Web Dimensions of I-section		
Height h_w	=	304.800 mm
Thickness t_w	=	38.100 mm

The following Figures shows the CAD Model and AVLB Assembly generated in Solid works (version 2014).

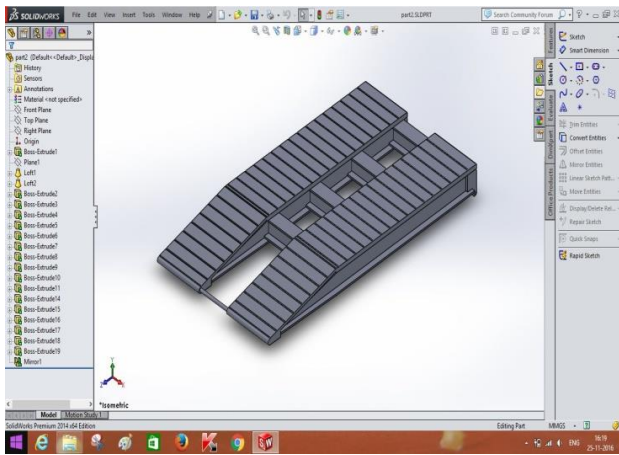


Fig. 3: 3D Model component (girder) of AVLB

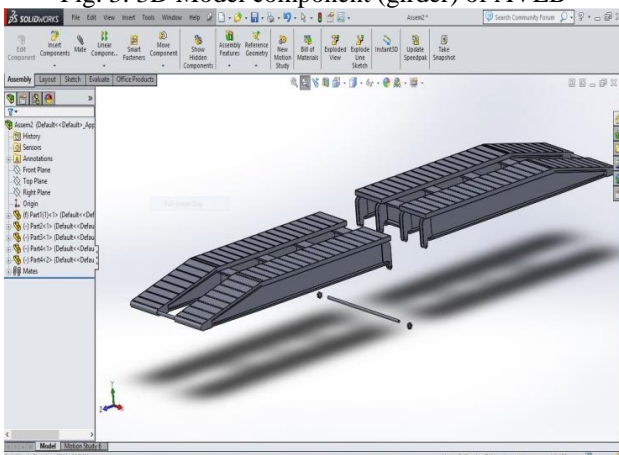


Fig. 4: Exploded view of AVLB Assembly in Solid works

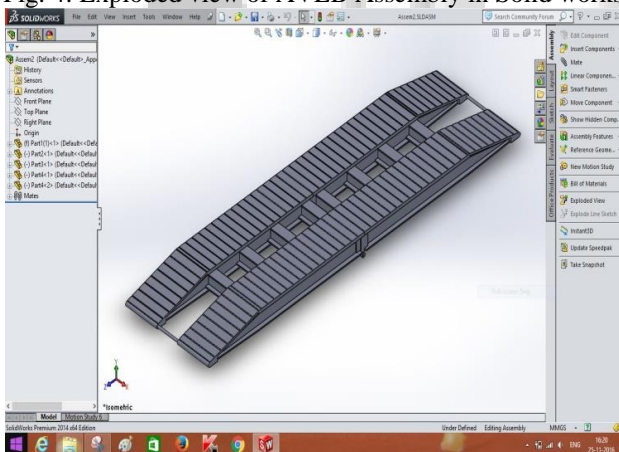


Fig. 5: Assembly of AVLB in Solid works

A Centered Pin-Joint (or) hinge joint placed between Modules of the Girders in a single bridge Span. The maximum stress will developed at center pin joints only. And In most of cases failure of Pin joint leads to failure in design of Heavy Assault Bridge. To overcome this Failure of Centre Pin-Joint. The previous Pin joint is replaced by Modified Hinge joint (or) pin joint. The following figure shows the modified Pin-joint used in Upgraded design of AVLB.

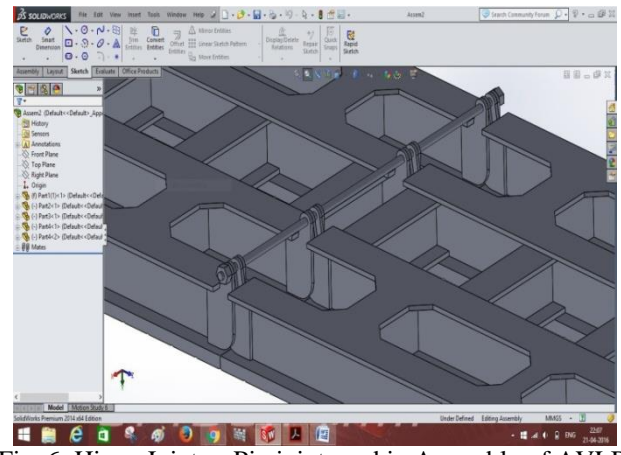


Fig. 6: Hinge Joint or Pin joint used in Assembly of AVLB Model.

V. FINITE ELEMENT ANALYSIS OF AVLB

In the Finite Element Modeling (FEM) and Finite Element Analysis (FEA) there are two most popular mechanical engineering applications offered by existing CAE systems. This is attributed to the fact that the FEM is perhaps the most popular numerical technique for solving engineering problems.

The method is general enough to handle any complex shape of geometry (problem domain), any material properties, any boundary conditions and any loading conditions. The generality of the FEM fits the analysis requirements of today's complex engineering systems and designs where closed form solutions are governing equilibrium equations are not available. In addition it is an efficient design tool by which designers can perform parametric design studying various cases (different shapes, material loads etc.) analyzing them and choosing the optimum design.

In this project the Static Structural analysis was carried out to study the structural integrity of the AVLB and identify the maximum stressed locations under various locations on launching bridge for 90 and 100 tonnes load conditions.

A. Static Analysis Of Avlb

The basic assumption in this analysis of AVLB is "the army vehicle weights on the launching bridge". The static stress analysis of AVLB is carried out by subjecting all components of the fuel tank for specified fuel load cases.

The following assumptions are made while doing analysis:

- Material is isotropic and linear elastic.
- The plate thickness is very small compared to its length and width.

Boundary Conditions & Loads: LOAD = 90 T & 100 T.

In this static analysis for AVLB 90 & 100 tonnes load, the load is applied in three cases and behavior of AVLB is observed.

- CASE-I: The body is arrested in all DOF at ends on the bottom faces and the load (90 tons & 100 tons) is applied at the centre on the top faces.
- CASE-II: The body is arrested in all DOF at ends on the bottom faces and the load (90 tons & 100 tons) is applied at the ends on the top faces.

- CASE-III: The body is arrested in all DOF at ends on the bottom faces and the load (90 tons & 100 tons) is applied at the slope end on the top faces.

B. Material Properties

All the components of the AVLB are made using hot-rolled structural steel **IS: 2062-1999, Grade -A, Fe 410WA**.
Chemical Composition of Material: (in % max values)

Composition	Value
Carbon %	0.23
Manganese Max %	1.5
Sulphur Max %	0.045
Phosphorous Max %	0.045
Silicon Max %	0.4
Carbon Equivalent (CE)	0.42

Table 1: Chemical Composition of IS: 2062-1999, Grade - A, Fe 410WA

C. Mechanical Properties

All the components of the AVLB are assigned as per the below material properties

Material properties	Value and units
Density	7.85e-006 kg /mm ³
Coefficient of Thermal Expansion	1.2e-005/ °C
Specific Heat	4.34e+005 mJ /kg. °C
Thermal Conductivity	6.05e-002 W/ mm. °C
Resistivity	1.7e-004 ohm mm
Compressive Yield Strength	250 MPa
Tensile Yield Strength	250 MPa
Tensile Ultimate Strength	460 MPa
Strength Coefficient	920 MPa
Strength Exponent	-0.106
Ductility Coefficient	0.213
Ductility Exponent	-0.47
Cyclic Strength Coefficient	1000 MPa
Cyclic Strain Hardening Exponent	0.2
Young's Modulus	200000 MPa
Poisson's Ratio	0.3
Bulk Modulus	166670 MPa
Shear Modulus	76923 MPa

Table 2: Mechanical Properties of IS: 2062-1999, Grade-A, Fe 410WA

The geometry of AVLB is imported into Ansys Workbench. The required material properties, mechanical properties were selected. Then a default mesh is generated for processing finite element analysis method. Due to meshing 64246 Nodes and 31829 Elements were produced.

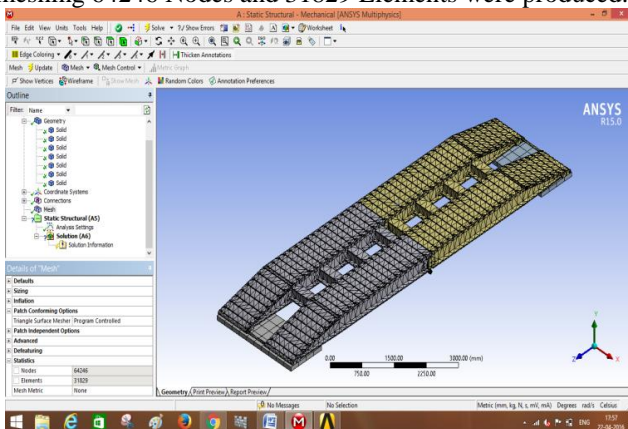


Fig. 7: Meshing Produced in ANSYS

The Analysis was done for the three cases of Static Structural Loading on AVLB for 90 tonnes and 100 tonnes to obtain the Simulation results.

The following figures show the three cases of Static Structural Load Analysis.

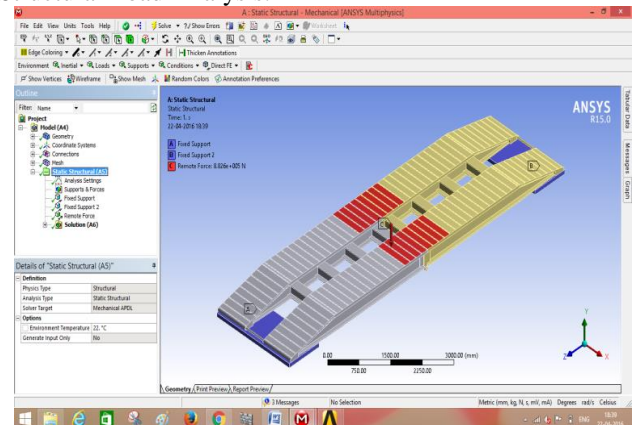


Fig. 8: CASE-I of Static Structural load ANSYS

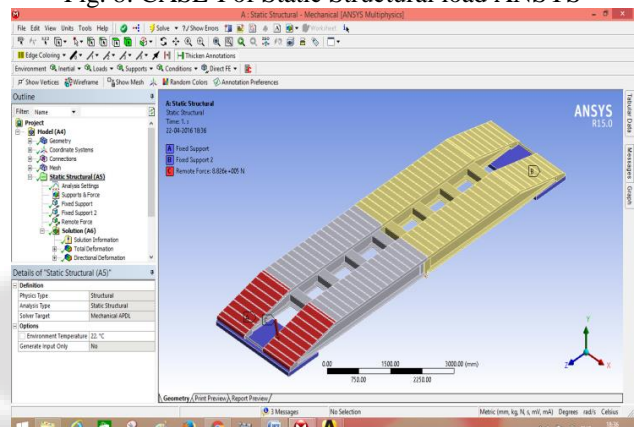


Fig. 9: CASE-II of Static Structural load ANSYS

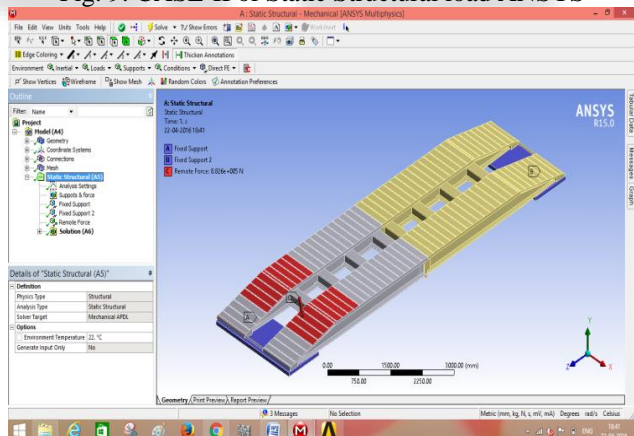


Fig. 10: CASE-III of Static Structural load ANSYS

VI. RESULTS AND DISCUSSION

A. Simulation Results of Static Structural Loads of 90 & 100 tonnes Loads on AVLB (CASE-I)

The AVLB is arrested in all DOF at ends on the bottom faces and the load (90 & 100 tons) is applied at the centre on the top faces.

its results Total Deformation, Directional Deformation, Equivalent Stress, Equivalent Elastic Strain, Factor of Safety, Reaction Forces ,Yield Strength is mentioned in the below table

Case-I				
	90tonnes load		100tonnes load	
	Maximum	minimum	Maximum	minimum
Total Deformation	3.9271 mm	3.1745 e-006 mm	4.3634 mm	3.5273 e-006 mm
Directional Deformation	4.4337 e-002 mm	-4.4839 e-002 mm	4.9263e-002 mm	-4.9821 e-002 mm
Equivalent Stress	123.4 MPa	8.7355 e-002 MPa	137.11 MPa	9.7061 e-002 MPa
Equivalent Elastic Strain	8.3272 e-004	4.381 e-007	9.2524e-004	4.8678 e-007
Yield Strength	250 MPa		250MPa	
Factor of Safety	2.0259		1.8233	
Reaction Forces 1	1.117 e+006 N		1.2411 e+006 N	
Reaction Forces 2	1.1196 e+006 N		1.244 e+006N	

Table 3: Simulation Results of AVLB Static Analysis for 90 & 100 tonnes Loads (Case-I)

1) Total Deformation Of AVLB For 90 & 100 Tonnes Loads (Case-I)

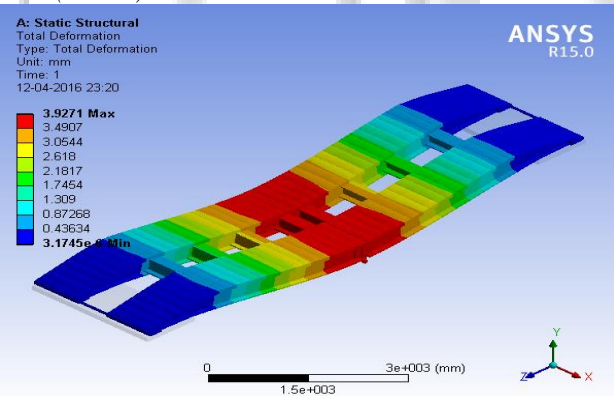


Fig. 11: Total Deformation of AVLB for 90 tonnes Loads (Case-I)

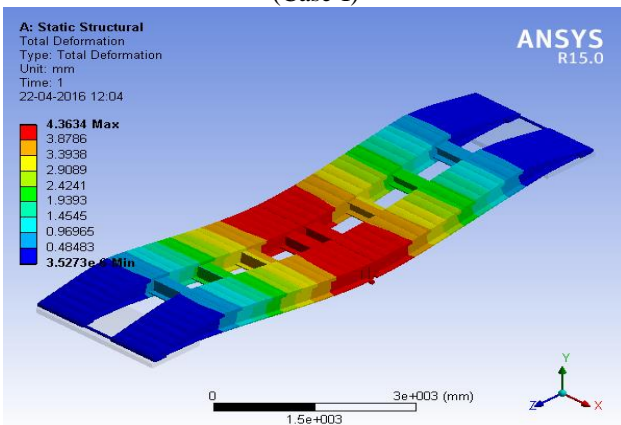


Fig. 12: Total Deformation of AVLB for 100 tonnes Loads (Case-I)

2) Equivalent Stress of AVLB for 90 & 100 tonnes Loads (Case-I)

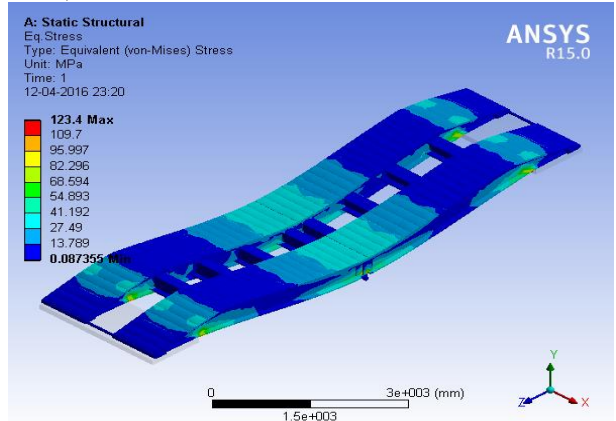


Fig. 13: Equivalent Stress of AVLB for 90 tonnes Loads (Case-I)

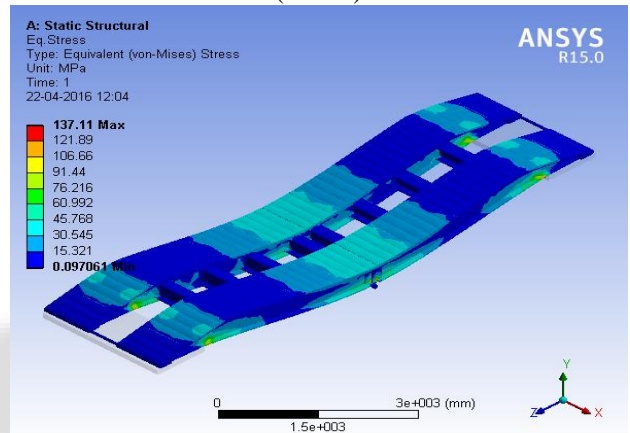


Fig. 14: Equivalent Stress of AVLB for 100 tonnes Loads (Case-I)

3) Factor of Safety of AVLB for 90 & 100 tonnes Loads (Case-I)

	90tonnes load		100tonnes load	
	Maximum	minimum	Maximum	minimum
Total Deformation	0.13161 mm	8.4207 e-008 mm	0.14624 mm	9.3564 e-008 mm
Directional Deformation	1.1311 e-002 mm	1.1762 e-002 mm	1.2568e-002mm	1.3068 e-002 mm
Equivalent Stress	18.19 MPa	4.1153 e-004 MPa	20.211 MPa	4.5726 e-004 MPa
Equivalent Elastic Strain	1.072 e-004	4.3065 e-009	1.1911e-004	4.785 e-009
Yield Strength	250 MPa		250MPa	
Factor of Safety	13.744		12.37	
Reaction Forces 1	9.07 e+005 N		1.0078 e+006N	
Reaction Forces 2	89227N		99141N	

Table 4: Simulation Results of AVLB Static Analysis for 90 & 100 tonnes Loads (Case-II)

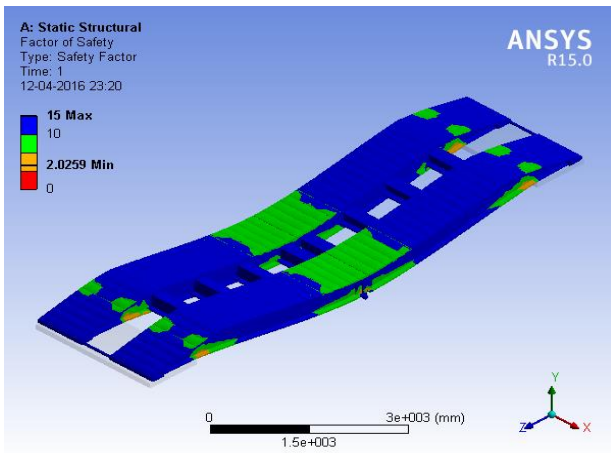


Fig. 15: Factor of Safety of AVLB for 90 tonnes Loads (Case-I)

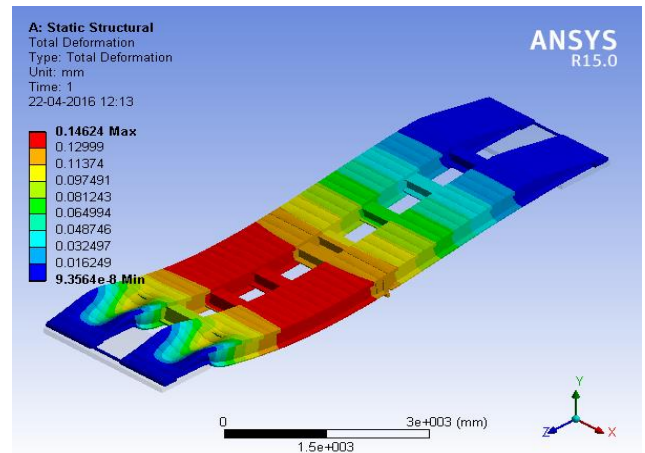


Fig. 18: Total Deformation of AVLB for 100 tonnes Loads (Case-II)

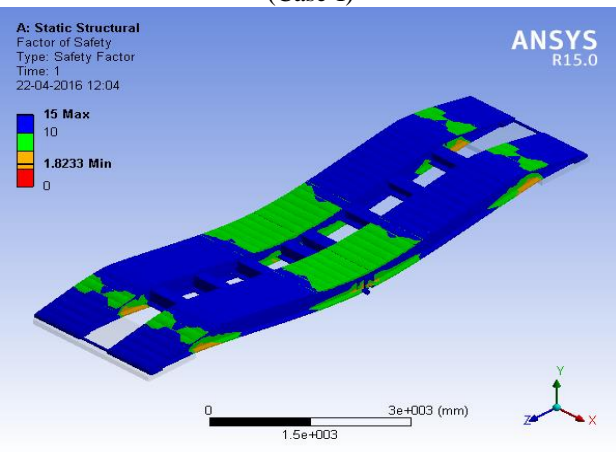


Fig. 16: Factor of Safety of AVLB for 100 tonnes Loads (Case-I)

2) *Equivalent Stress of AVLB for 90 & 100 tonnes Loads (Case-II)*

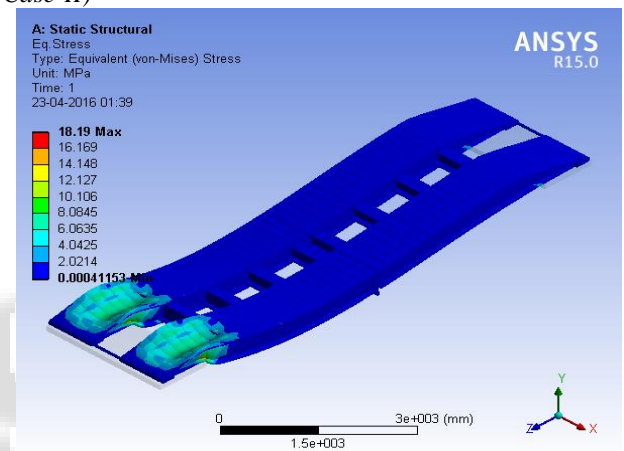


Fig. 19: Equivalent Stress of AVLB for 90 tonnes Loads (Case-II)

B. *Simulation Results of Static Structural Loads of 90 & 100 tonnes Loads on AVLB (CASE-II)*

The body is arrested in all DOF at ends on the bottom faces and the load (90 & 100 tons) is applied at the ends on the top faces.

its results Total Deformation, Directional Deformation, Equivalent Stress, Equivalent Elastic Strain, Factor of Safety, Reaction Forces, Yield Strength is mentioned in the below table.

1) *Total Deformation of AVLB for 90 & 100 tonnes Loads (Case-II)*

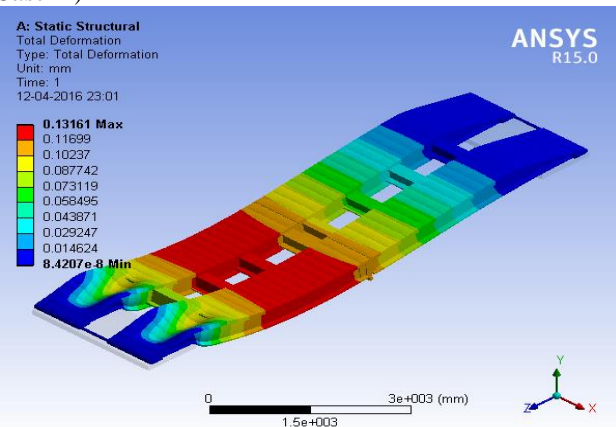


Fig. 17: Total Deformation of AVLB for 90 tonnes Loads (Case-II)

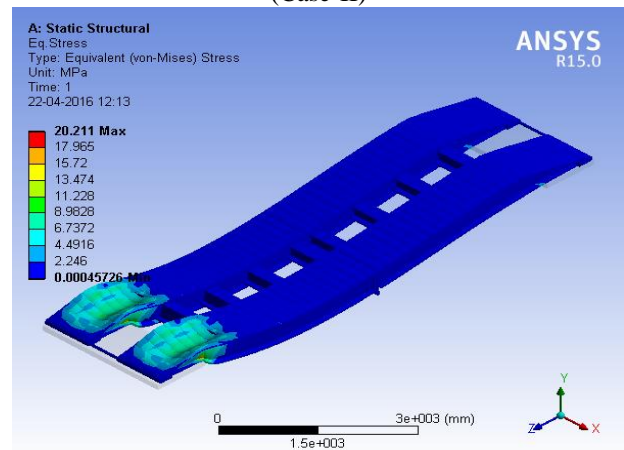


Fig. 20: Equivalent Stress of AVLB for 100 tonnes Loads (Case-II)

3) Factor of Safety of AVLB for 90 & 100 tonnes Loads (Case-II)

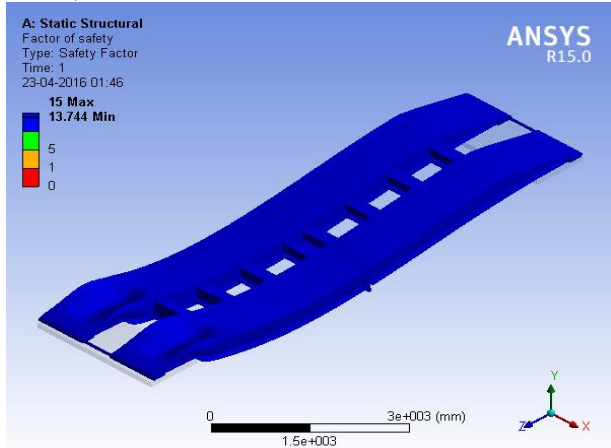


Fig. 21: Factor of Safety of AVLB for 90 tonnes Loads (Case-II)

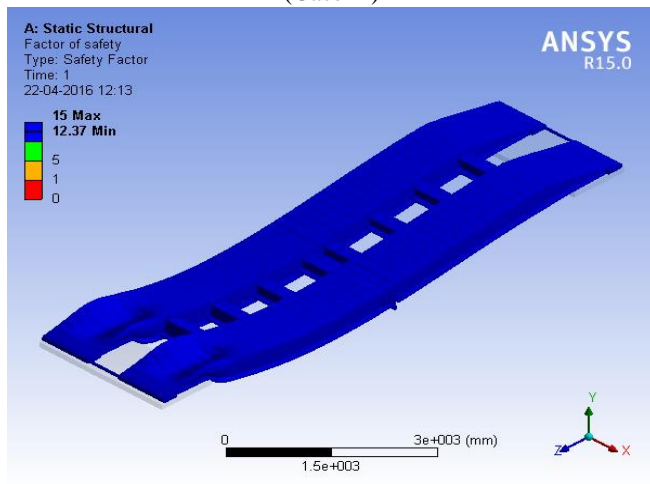


Fig -22: Factor of Safety of AVLB for 100 tonnes Loads (Case-II)

6.3 Simulation Results of Static Structural Loads of 90 & 100 tonnes Loads on AVLB (CASE-III)

	90tonnes load		100tonnes load	
	Maximum	minimum	Maximum	minimum
Total Deformation	0.72373mm	2.3967e-007 mm	0.0841 mm	2.663e-007 mm
Directional Deformation	2.3755e-002 mm	-2.3547e-002 mm	2.6394e-002m	--2.6163e-002 mm
Equivalent Stress	52.028 MPa	2.2465e-003 MPa	57.808 MPa	2.4962e-003 MPa
Equivalent Elastic Strain	3.055e-004	1.127e-008	3.3949e-004	1.2522e-008
Yield Strength	250 MPa		250 MPa	
Factor of Safety	4.8051		4.3246	
Reaction Forces 1	8.6009e+005 N		9.5566e+005 N	

Reaction Forces 2	3.4334e+005N	3.8149e+005 N
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Table 5: Simulation Results of AVLB Static Analysis for 90 & 100 tonnes Loads (Case-III)

4) Total Deformation of AVLB for 90 & 100 tonnes Loads (Case-III)

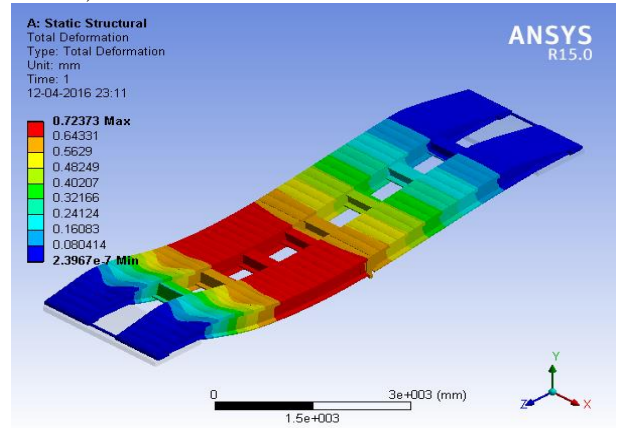


Fig. 23: Total Deformation of AVLB for 90 tonnes Loads (Case-III)

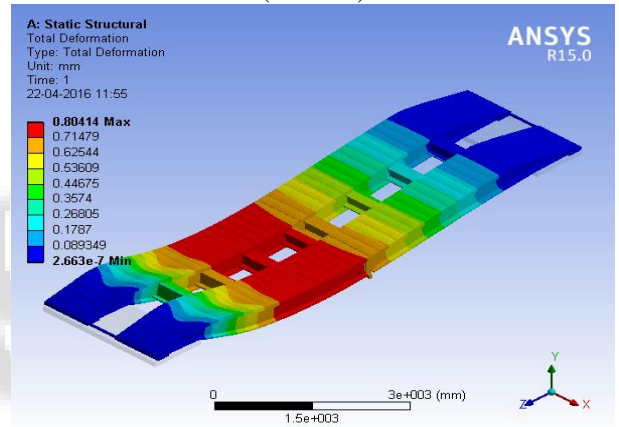


Fig. 24: Total Deformation of AVLB for 100 tonnes Loads (Case-III)

5) Equivalent Stress of AVLB for 90 & 100 tonnes Loads (Case-III)

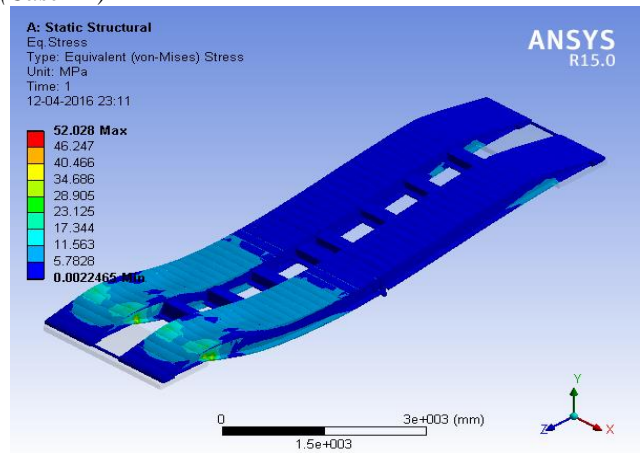


Fig. 25: Equivalent Stress of AVLB for 90 tonnes Loads (Case-III)

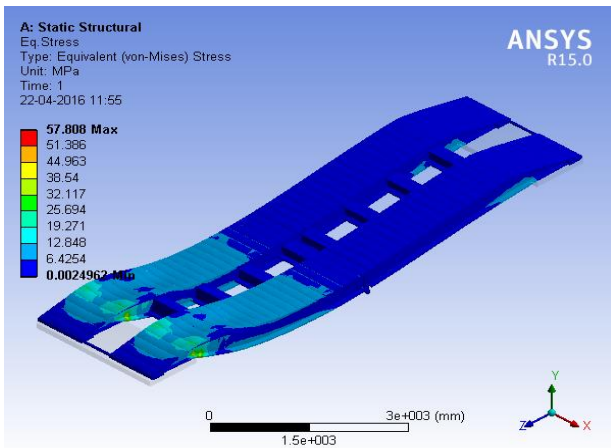


Fig. 26: Equivalent Stress of AVLB for 100 tonnes Loads (Case-III)

6) Factor of Safety of AVLB for 90 & 100 tonnes Loads (Case-II)

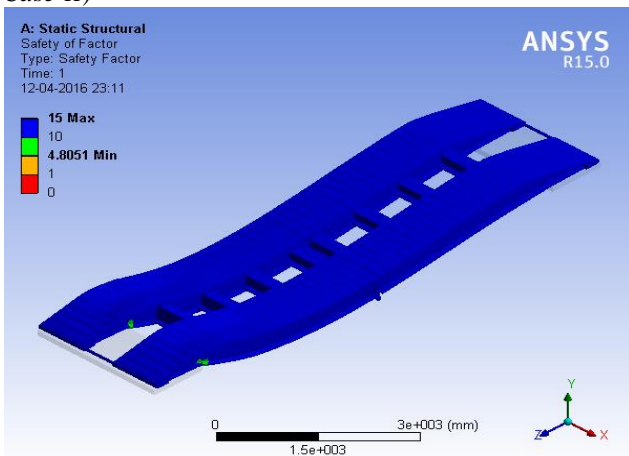


Fig. 27: Factor of Safety of AVLB for 90 tonnes Loads (Case-III)

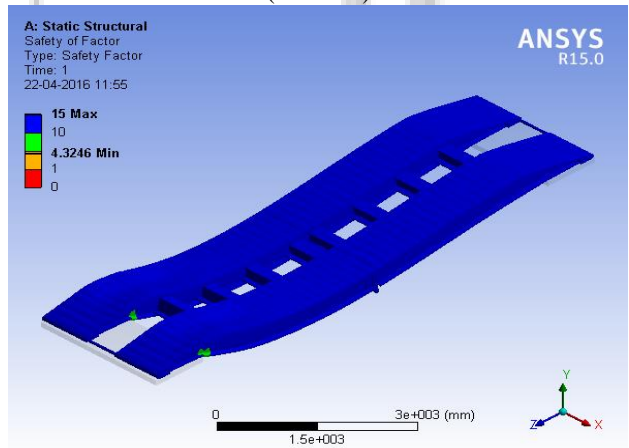


Fig. 28: Factor of Safety of AVLB for 100 tonnes Loads (Case-III)

VII. CONCLUSIONS

The Static analysis was carried out on the AVLB model for 90tonnes and 100tonnes load at three cases. And the Following Table shows the result values of Maximum Stress, Yield strength and factor of Safety.

From the above table it can be observed clearly that the maximum stresses values in three cases are lesser than yield strength of the launching bridge material i.e.; 250Mpa.

Thus according to the Von-Mises Stress Theory, the Von-Mises stress is more than the yield strength of the material. Hence the design of AVLB is safe for the both 90Tonnes and 100Tonnes loads.

RESULT						
LOAD: 90Tonnes			LOAD: 100Tonnes			
CAS E NO:	I	II	III	I	II	III
MAX STR ESS	123.4 MPa	18.19 MPa	52.028 MPa	137.11 MPa	20.211 MPa	57.808 MPa
YIELD STR ENG TH	250 MPa	250 MPa	250 MPa	250 MPa	250 MPa	250 MPa
Factor of Safety	2.0259	13.744	4.8051	1.8233	12.37	4.3246

Table 6: Conclusion Table

As considerable values of Factor of safety was obtained in all three cases indicates the modified design is safe. But the factor of safety was 1.823 in case-I, 100tonnes. The most Preferable value of factory of safety should be ≥ 2 in the most cases to ensure additional safety to the design. It states that the design is under safe limits for 100 tonnes load also.

From the principle of Von-Mises Stress Theory, General principles of safety factors the modified design of AVLB is safe for the above operating loads 90 tonnes and 100tonnes.

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