International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

Design and Analysis of Bus Passenger Seat as Per AIS-023

T. A. Jadhav
Department of Mechanical Engineering,
Sinhgad College of Engineering, Vadgaon, (Bk), Pune,
411041, Maharashtra, India

G. S. Thakare
Department of Mechanical Engineering,
Sinhgad College of Engineering, Vadgaon, (Bk), Pune,
411041, Maharashtra, India

***Abstract*— Buses are known to be one of favourite modes of public transport. During frontal crash, passenger seating from second row and further back, impacts seat in front of them. If seat structure doesn't change its position, it can lead to severe injuries. Aim of this project is to reduce injury pattern of passenger during frontal crash. This is accomplished by studying standard, creating mechanism to achieve deflection and strength results. Design of seat structure is tested by performing Finite element Analysis (FEA). FEA is performed in Hypermesh, Ls-Dyna and Hypergraph software to predict deflection of backrest frame at two different locations. To calculate deflection impact analysis was carried out by applying load at two locations. Loads used for analysis are taken from Automotive Industry Standard (AIS-023). Physical model is prepared after getting satisfactory results from FEA. Testing of Physical model is carried out in laboratory. Results show overall 11% deviation in FEA and Experimental results.**

Keywords— AIS-023, Frontal Crash, Occupant Injury, Seat

I. INTRODUCTION

Buses are popular means of public transport and using them always helps to reduce the fuel consumption overall and it helps to handle economical and ecological challenges in front of society. Studies shows using public transport not only reduce consumption of fuel per individual but also resulting in less emission in environment. However to cater the rising number of population increase of vehicles are required. An increase in number of vehicles will increase the probability of their involvement in road accidents. Passenger seats carry most integral part in safety as back of the seats are impact surface and will work as restrains when occupants are not wearing seat belt. During frontal crash passengers seating will get injured by hitting seat in front of them. The improper seat design will lead to severe head, chest and leg injuries. To eliminate risk of severe injury seat structure should absorb the sufficient impact energy and reduces injury. Haining Chen et al. [1] carried out simulation of bus seat behavior for frontal and rear crashes. To improve efficiency structure optimization was conducted on critical areas and additional reinforcement was used to strengthen various parts. This work found out few modifications in design will lower the risk of injuries of occupant. Leslaw Kwasniewski et al. [2] studied crashworthiness and safety of passengers. Various Finite Element models were generated on the basis of previous study and nonlinear explicit dynamic codes were used to show numerical approach. This work concluded that reduced cost of FE analysis was becoming reliable and widely acceptable in industry. Zhigang Li et al. [3] conducted experimental test to evaluate the injuries suffered on neck during frontal collision of school bus. Various sled test results shows to reduce serious neck injuries school bus should equipped with lap/shoulder belts. Gerardo Olivares et al. [4] carried out study on injury mechanism for bus accidents by simulating and testing the model in laboratory. Seat was tested on series of sled test with 5^{th}, 50^{th}, 95^{th} percentile dummy occupants in seats and concluded avoiding installation of side facing seats and rear impact may causes neck extension injury due to low back seat designs. S. Dudhbhate et al. [5] conducted work on performance enhancement of school bus seat as per AIS-023 through FEA and validation. Bracket was introduced to restrain seat during frontal impact and injury was predicted on the basis of FMVSS 208 standard. Resulted strength and deflection are well within allowable limits and head, neck, chest, leg injuries also are within limit. Hsing-Chung chu [6] carried out different types risk factors affecting severe crashes for long distance travel.

In India according to Government report on Road accident in India – 2017 by Ministry of road Transport and highway transport Research wing shows in bus accidents 12,088 passengers were killed, 50,686 passengers were injured and resulting 7.8% in total accidents in India [7].The passenger bus seat structure should provide sufficient strength and deflection are ensured by AIS-023 with amendments 1 and 2 [8]. Similar to AIS-023, European Union uses United Nation Economic Commission for Europe (UNECE) R17 and United States of America uses Federal Motor Vehicle Safety Standard 208 (FMVSS) as a safety standard for bus passenger. In addition to strength and deflection requirement this standard also includes dynamic test with injury prediction of the occupant at different body part.

Aim of this work is to make bus transport safer by reducing the injury pattern of passenger during frontal crash of bus. Initially requirement for tests were studied. Finite element analysis of seat structure was carried out in industry software. Experimental analysis was carried out on prototype of seat structure. Results from both analysis were compared.

II. STRENGTH REQUIREMENT TEST FOR SEATS

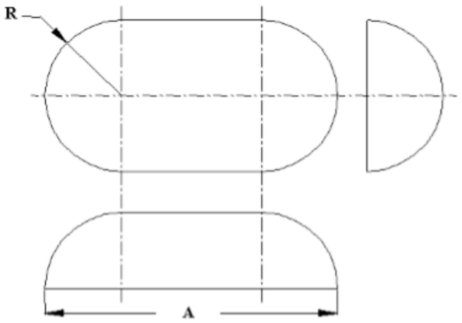
AIS-023 is mandatory safety standard applicable for bus passenger vehicles in India. AIS-023 was formulated to cover the safety need required in bus passenger vehicle carrying more than 8 people. Standard specifies various dimension and strength and deflection requirement. This test is not mandatory for side facing, reward facing or sleeper seat category.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

To determine strength and deflection of seat structure and anchorages, Static forces are applied at back of the seat simultaneously. Static Force Application Device (SFAD) and test procedures are described as follows.

A) SFAD – Test Apparatus

Static Force Application Device *(SFAD*) is a device used to apply force on back of the vehicle and it consist of two semi-cylindrical objects used to apply the force at back of the seat at upper form at height H_1 and lower form at height at H_2 from base plane.Dimension for lower form as shown in Fig. 1. Radius of lower form 82 mm with tolerance of 3 mm and width lies between 320 to 330 mm. Number of lower form depends on the capacity of seat.



R = Radius of Curvature (82 mm ± 3);
A = Width of Cushion (320 to 330 mm)
Fig. 1. Dimension for Lower Form

Radius of upper form is equal to lower form but the width of upper form span greater than width of seat. SFAD should have higher rigidity as compared to seat structure during test. Device should be equipped with force transducers to measure the applied force with deflection seat. Fig. 2 shows CAD model used for Analysis of seat structure. Fig. 3 shows experimental setup of Static Force Application Device (SFAD).

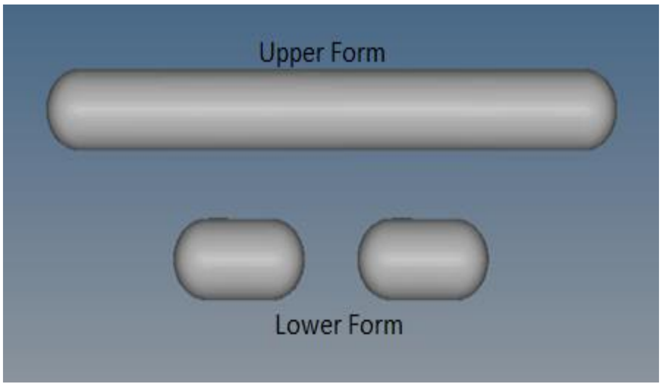


Fig. 2. CAD Model of Upper and Lower Form

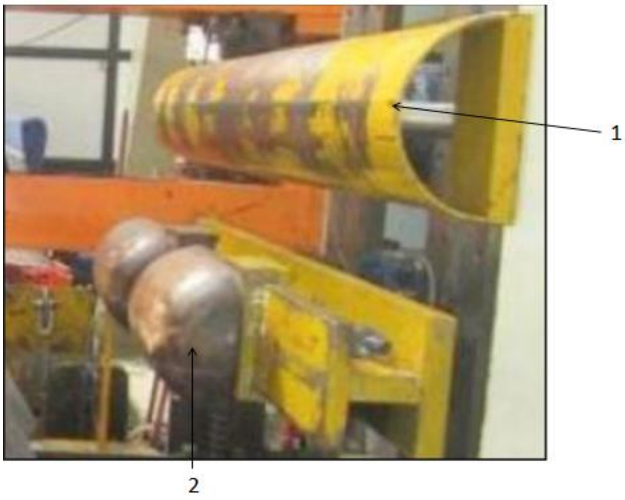


Fig. 3. Experimental Setup of SFAD; 1. Upper Form; 2.Lower Form

B) Test Procedure

To check whether seat will deflect on whether applying load and avoid complete collapse this test is done. At two locations forces are applied, simulating as contact points representing human head and knee area during impact.

The force applied at upper form is calculated from equation (1)

$$F_1 = \left(\frac{1000}{H_1}\right) * N \quad (1)$$

where N = Number of passenger
Force is taken with tolerance of 50 N acting at height H_1 which is in between 700 mm to 800 mm and above the reference plane. Reference plane is plane passing through the point of contact of heels of the passenger. The direction of application of force shall be situated in the vertical plane of seating position concerned. It should act horizontal and from rear towards the front of seat at a height H_1.
The force applied at lower form is calculated from equation (2)

$$F_2 = \left(\frac{2000}{H_2}\right) * N \quad (2)$$

where, N = Number of passengers
The force shall be applied simultaneously to rear of seat structure corresponding for number of seating position of the seat in the same vertical plane and in the same direction at height H_2 which lies between 450 mm to 550 mm above the reference plane. Table I shows Load applied at H_1 and H_2.

Table I Load Application at Contact Points

	Upper Form	Lower Form
H_1(mm)	800	N.A.
H_2(mm)	N.A.	500
Force(kN)	2.5	8

III. FINITE ELEMENT ANALYSIS

Dimension for Seat Structure was taken from AIS-023 Standard. Standard suggest various dimensions such as minimum torso angle, width of seat etc. To reduce the risk of injury, compartmentalization technique was used, in which the distance between two consecutive seats were minimized to reduce the stooping distance of occupant after impact.

Mechanism was used to provide the required strength and deflection required by standard. Various types of mechanism were tried and tested, linkage mechanism was selected on the basis of simplicity, low cost and easy to manufacture. In which solid rod was used to transfer the load from back side of seat structure to complete frame. In addition small pin was used to join the solid rod and base tube which was design such that it will carry certain load and brakes after some initial loading which will provide deflection required. Deflection and strength result were achieved by introducing linkage mechanism.

A) Finite Element Model of Seat Structure

Modeling part was carried out in CATIA software and model file will be used in HYPERMESH for pre processing. Fig. 4 shows CAD model of bus seat structure.

Fig. 4. CAD Model of Seat Structure

B) Material Properties

Seat structure mainly contains IS: 4923 commonly known as Carbon Steel in square and rectangular tubes, for circular tubes IS: 1161 Electric resistance Welded (ERW), for Sheets IS: 2062 which is Hot rolled sheet were used for bracket, plates. The mechanical properties of these materials are shown in Table II.

Table II Mechanical Properties of Material

Structure	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	% Elongation
Tubes	450	310	14
HR Sheet	410	250	23

C) Mesh Model of Seat Structure

In crash analysis, normally 2D mixed mesh is done in which percentage of tria element will kept low because model become stiff. Rotating quads were avoided to get transfer of energy linear if not it will cause disturbance in transfer of energy. Minimum element length was kept low to reduce computational time. Solid rod in mechanism was meshed with hexa mesh. Meshing of seat structure was carried out in HYPERMESH and meshed file was used in LS-DYNA explicit for Processing part.. Fig.5. shows mesh model of seat structure.

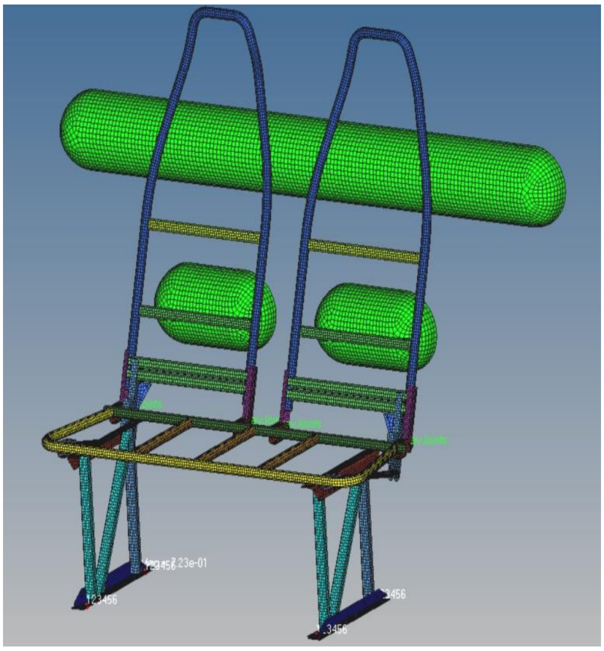


Fig. 5. Mesh Model of Seat Structure

D) Boundary Conditions

As standard suggest legs were fixed and two loads were applied at height H_1 and H_2 and all degree of freedom were restrained for anchorages. These force values were applied gradually in 0.20 sec and maintained. Forces of 2.5kN and 8kN are acting on a seat structure at height 800 mm and 500 mm respectively. Fig. 6 shows Load v/s Time history for lower and upper form. Fig. 7 shows loads acting at H_1 and H_2.

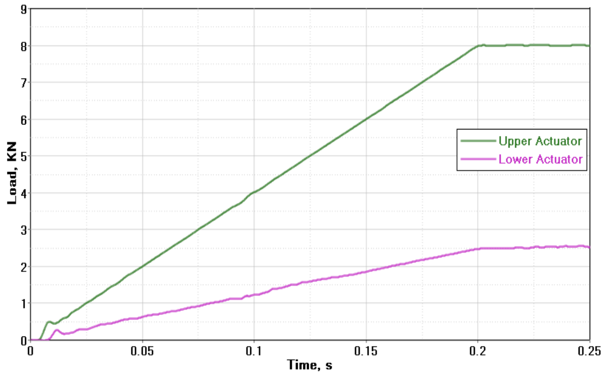


Fig. 6. Load Time history used in Simulation for Upper and Lower form

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

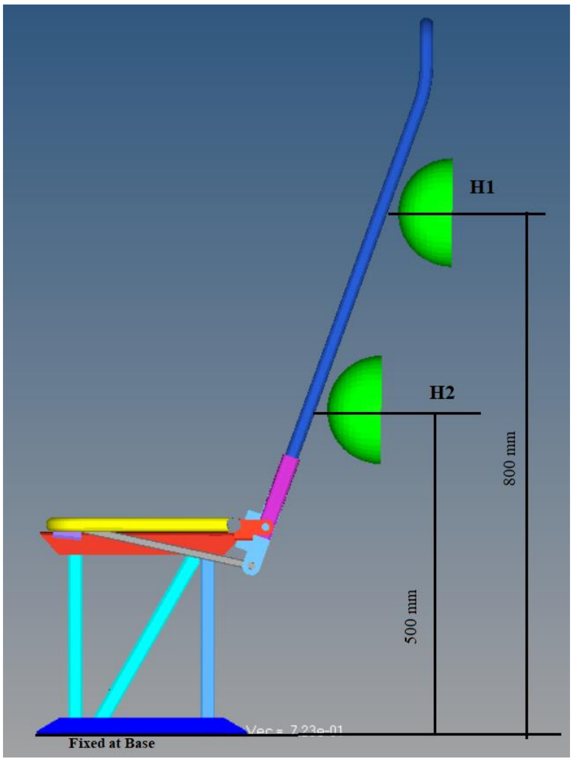


Fig. 7. Boundary Condition on Seat Structure

E) Simulation of Seat Structure

LS-DYNA Explicit software was used for processing. Hyperworks was used Post processor to view results. All the test conditions were taken from AIS standard. Deflection of seat structure shows it is well within the specified limit. Fig. 8 shows the initial state of seat structure. Fig. 9 Shows final position of seat structure.

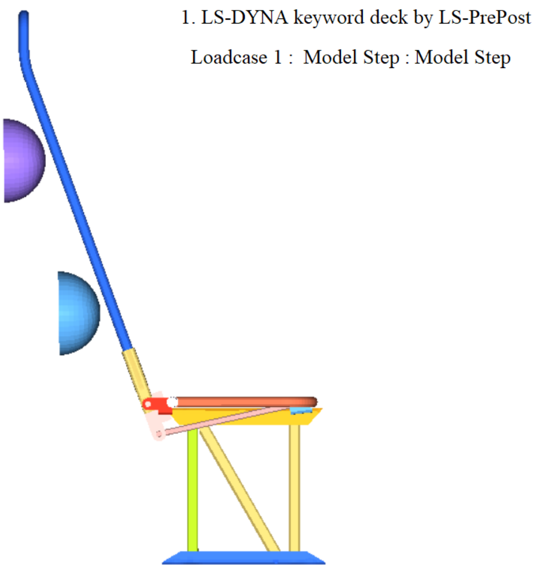


Fig. 8. Initial position of Seat Structure

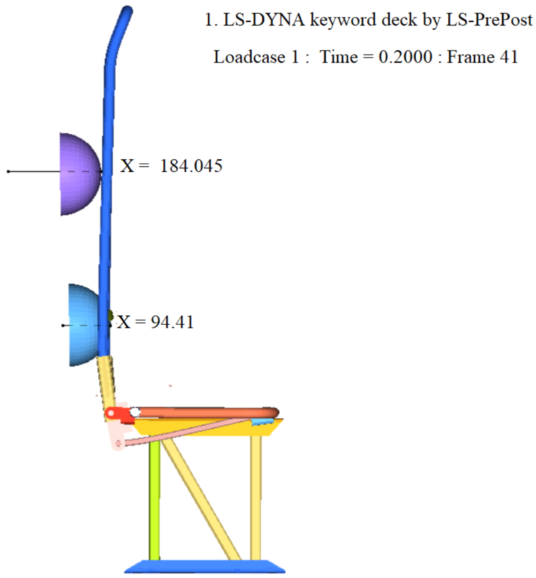


Fig. 9. Final Position of Seat Structure

Deflection for H_1 is 184.045 mm and deflection for H_2 is 94.41 mm which was well within standard limit. Fig . 10 shows deflection at Upper and Lower form for experimental analysis.

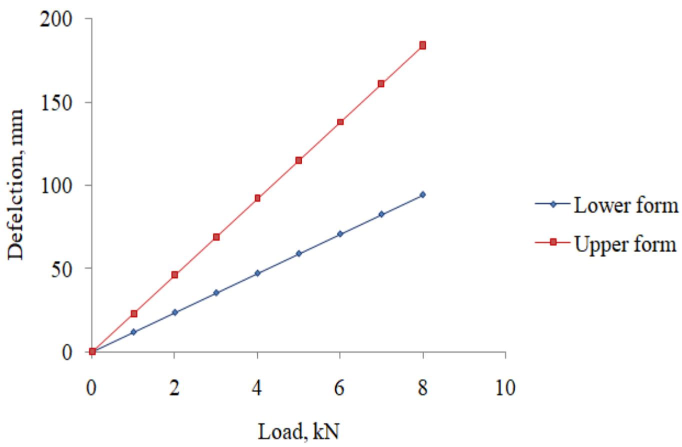


Fig. 10. Load v/s Deflection for FE analysis

IV. EXPERIMENTAL ANALYSIS

To perform experimental analysis all required procedure were taken from automotive industry standard (AIS-023). Here seat legs were fixed by using means of fasteners such as nuts and bolts at its position. To apply loads Static Force Application Device were used on upper form at H_1 and lower form at H_2.Initial position of SFAD was determined by bringing test device into contact with a Force of 20 N until it makes indentation seat surface. After fixing initial position of SFAD, load was applied gradually at upper and lower form in 0.2 sec to find structural deformation of seat structure. Final results are calculated by using electronic transducers connected to SFAD. Table III shows deformation at Upper and Lower form of seat structure.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

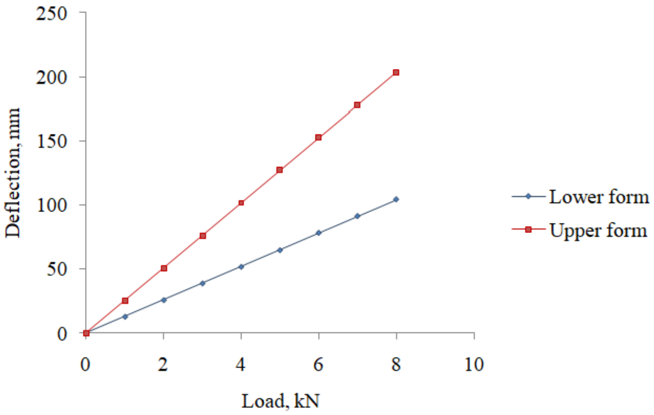


Fig. 11 Load v/s Deflection for Experimental Analysis

Table III Deformation at Contact Points

	Force (kN)	Deformation
Upper Form	2.5	203
Lower Form	8	104

V. RESULTS

Load v/s deflection curve of FEA test for lower and upper form was compared. Compared test results show little deviation in Experimental with FEA results. In FEA, both curves of Lower and Upper form are causing constant deflection throughout load application. In FEA analysis, deflection for H_1 is 184.045 mm and deflection for H_2 is 94.41 mm. But Experimental test results shows, deflection at H_1 was 203mm and at H_2 deflection was 104 mm.

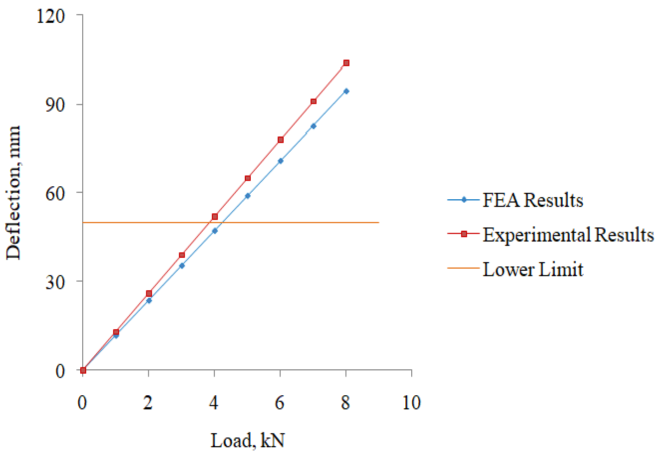


Fig. 12.Load v/s Deflection of H_2

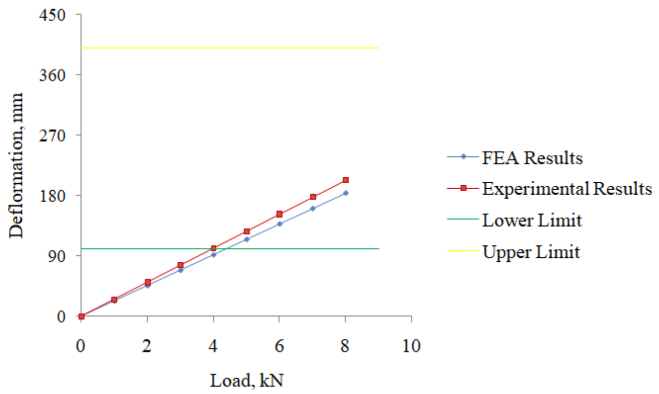


Fig. 13.Load v/s Deflection of H_1

Both the results shows 11% higher deflection in experimental than the FEA analysis. Results from Finite element analysis and experimental test results are well within the allowable limit as per Automotive Industry Standard.

VI. CONCLUSIONS

AIS-023 standard mainly focuses on seat strength evaluation for bus passenger seats. Initially Finite element model was prepared as per AIS-023 standard and validated with physical test results. Simulation and experimental test results were having small deviation in them. The deflection values of seat at H_1 and H_2 are well within limit. Overall good correlation was observed between simulation and test results.
Further improvement is possible by implementing seat belts and other safety features to avoid risk of serious injury during frontal crash. In addition to this we can calculate relation between sled test and static test which are used to evaluate strength in bus seat in foreign countries with injury prediction.

REFERENCES

[1] Haining Chen, Hao Chen, Liangjie Wang, “Analysis of vehicle seat and research on structure optimization in front and rear impact”, World Journal of Engineering and Technology, 2014, 2, 92-99.
[2] Leslaw Kwasniewski, Cezary Bojanowski, Jeff Siervogel, Jerry W. Wekezer, Krzystof Cichocki.” Crash and safety assessment program for paratransit buses”, international journal impact engineering, International Journal of Impact Engineering 36(2009) 235-242.
[3] Zhigang Li, HaoGe, Jinhuan Zhang, Yonghua Zhu, “The necessity of evaluating child neck injuries in frontal collision of school bus for transportation safety”, Safety Science 62 (2014) 441-449.
[4] Olivares, G., Yadav V., “Structural Crashworthiness of Mass Transit Buses During Frontal Collisions.” International Crashworthiness Conference, Tokyo, Japan, July 2007, Paper number 09-0427.
[5] S. T. Dudhbhate, T. A. Jadhav, “Performance Enhancement of School Bus Seat as per AIS-023 through FEA and validation”, International Engineering Research Journal, Special Issue 2, Page 2428-2433, 2015.
[6] 6.Hsing-Chung Chu, “Assessing factors causing severe injuries in crashes high-deck buses in long distance driving on freeways”, Accident Analysis and Prevention 62 (2014) 130-136.
[7] 7.Ministry of Road Transport and Highway’s, Road accidents in India – 2017, INDIA.
[8] 8.Automotive Vehicles- Seats, their Anchorages and Head Restraints for passenger vehicles of Categories M2, M3 and Goods Vehicles of Category N- Specification, Automotive Industry Standard (AIS-023), August- 2017.