# PROGRESSIVE DEFORMABLE BARRIER (PDB) – EVALUATION OF IT'S IMPACT ON SMALL CAR DESIGNS THROUGH CAE ANALYSIS.

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## ABSTRACT

Progressive Deformable Barrier (PDB) based offset test method was recently proposed as an alternative to the existing regulatory test using Offset Deformable Barrier (ODB) as per ECE R94. Implications of this change on structural design of cars were studied through CAE simulations.

Comparative simulations were run with the two barriers for vehicles with different mass and effect of the barrier change was studied against the mass of the vehicle. Stiffness improvements required in car structures for similar intrusions when PDB was used were then studied. The study showed that PDB was able to absorb a lot more energy compared to ODB and this could essentially mean the car structures can be engineered with reduced energy absorbing capability while still meeting the requirements with PDB.

## INTRODUCTION

A new test procedure using PDB was proposed vide GRSP/2007/17, in place of current ECE R94 offset frontal impact test procedure. The comparison of the proposal is as follows:

| Parameter | ECE R94 | French proposal |
|---|---|---|
| Barrier | EEVC | PDB |
| Test speed (kmph) | 56 | 60 |
| Overlap (%) | 40 | 50 |

The implications of these changes are studied on structures of passenger cars and SUVs using CAE. The FE model of the PDB, used in study, was developed in Tata Motots. The FE model was validated with the test data available in the literature. (1) An overlay of the PDB and ODB is shown in Figure1. PDB is deeper and does not have the bumper elements.

## PDB FE MODEL BUILD AND VALIDATION

The PDB FE model was built using a combination of brick and discrete elements. The stiffness of different cores of the barrier available in literature was used to define the stiffness of the FE model (Figure 2). The FE model of PDB was then validated with two physical tests. The test details and the physical test results were taken from the literature. (1)

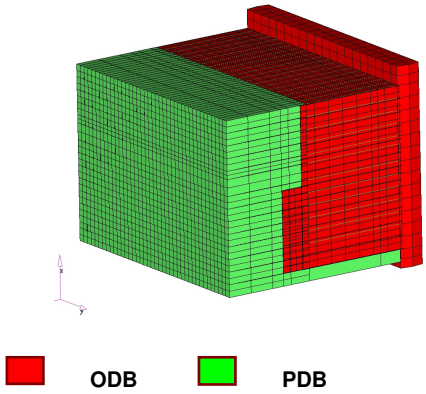


**Figure 1. Overlay of ODB and PDB.**

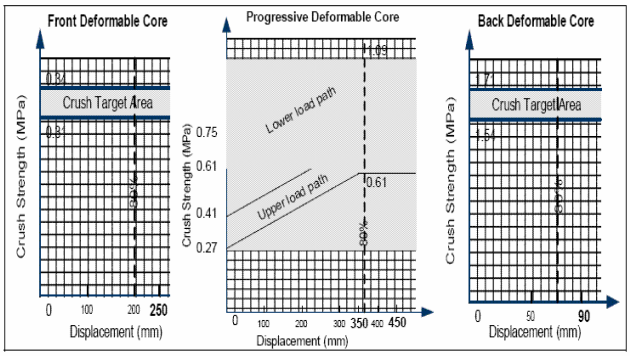


**Figure 2. PDB core stiffness (1).**

Test1: In This test a 1300kg offset flat rigid barrier impacts on the PDB at a speed of 60 kmph as shown in Figure 3. The requirement is that the resistance offered by PDB should lie in the corridor as sown in Figure 4.The performance of PDB Fe model in this test is given in Figure 4. The PDB FE model met the requirement of this test.

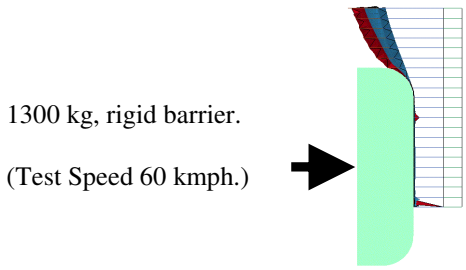


**Figure 3. PDB validation Test1**

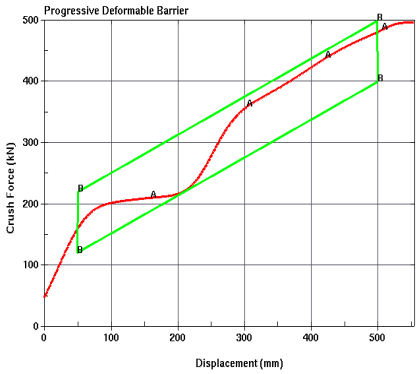


**Figure 4. PDB resistance w.r.t. its Deformation.**

Test 2: In this test a 1300 kg offset rigid tubular barrier impacts the PDB at a speed of 60kmph. The resistance offered by the PDB is required to lie within the corridor shown in the Figure 6. The FE model of PDB met this requirement.

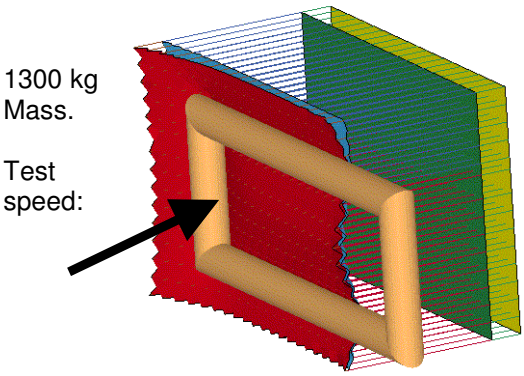


**Figure 5. PDB FE model validation Test2.**

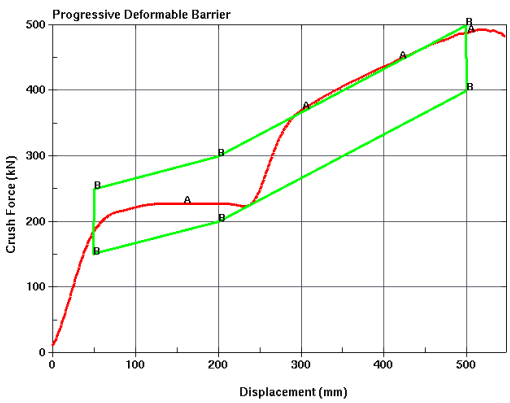


**Figure 6. PDB resistance w.r.t. its Deformation.**

**ODB VS PDB stiffness comparison**:

To compare the ODB and PDB stiffness, Simulations are carried out with flat rigid barrier. Following graph shows the comparison of PDB and ODB barrier stiffness upto 400 mm of crush. It was observed that as the crush increases the PDB has higher stiffness than ODB (Figure 7).

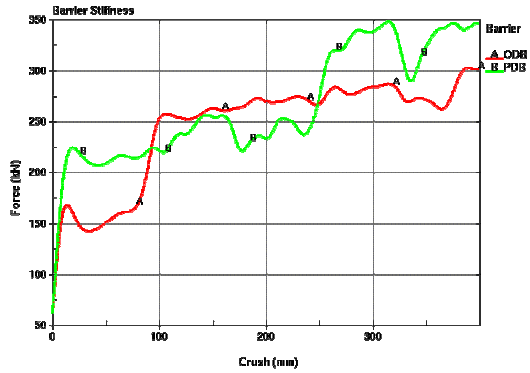


**Figure 7. Stiffness comparison of ODB and PDB.**

The validated PDB FE model was used for full vehicle crash simulations. Simulations were carried out for cars and for SUVs to study the structural crash performance with PDB and ODB.

- Passenger car with kerb wt of 750 kg.
- Car with kerb wt of 1100 kg.
- SUV with kerb wt of 2400 kg.

**Passenger car with 750 kg kerb weight**

The comparison of full vehicle ODB56 and PDB60 simulation results is given in the Table1 below. The critical parameters like energy absorption, intrusions and the crash pulse are used for comparison.

**Table1. ODB56 VS PDB60 result comparison for small car.**

| Sr.no | Description | ODB 56 | PDB 60 |
|---|---|---|---|
| 1 | Initial Kinetic Energy (kJ) | 119 | 131 |
| 2 | Energy absorbed by the vehicle (kJ) | 40 | 54.3 |
| 3 | Energy absorbed by the barrier (kJ) | 53 | 57.3 |
| 4 | Residual kinetic energy (kJ) | 11.5 | 10.8 |
| 5 | Energy lost in Friction and Miscellaneous Energy (kJ) | 14.5 | 8.6 |
| 6 | Stopping distance X (mm) | 645 | 550 |
| 7 | Time to zero X velocity (ms) | 76 | 58 |
| Intrusion (Percentage change w.r.t ODB56)) | | | |
| 1 | Peak steering column intrusion X | | +45 |
| 2 | Peak A pillar (Top) X-intrusion | | +45 |

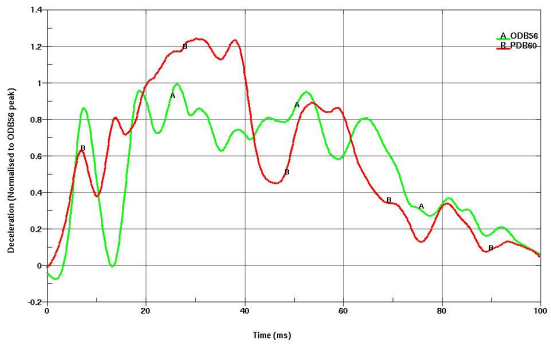


**Figure 8.ODB56 Vs PDB60 crash pulse for small car.**

The Effect of replacing ODB56 with PDB60 on small cars is summarized below.

- Overall deformation of vehicles structure increased.
- Resulting pulse is stiffer
- Resulting intrusions are higher

**Passenger car with 1100 kg kerb weight**

The comparison of structural crash performance of 1100 kg car with ODB56 and PDB60 is given in Table 2. The crash pulse comparison is given in Figure 9.

**Table 2. ODB56 VS PDB60 result comparison for mid sized car.**

| Sr.no | Description | ODB 56 | PDB 60 |
|---|---|---|---|
| 1 | Initial Kinetic Energy (kJ) | 177 | 196 |
| 2 | Energy absorbed by the vehicle (kJ) | 68 | 113 |
| 3 | Energy absorbed by the barrier (kJ) | 75 | 59 |
| 4 | Residual kinetic energy (kJ) | 13.2 | 7.8 |
| 5 | Energy lost in Friction and Miscellaneous Energy (kJ) | 20.8 | 16.2 |
| 6 | Stopping distance X (mm) | 880 | 815 |
| 7 | Time to zero X velocity (ms) | 90 | 80 |
| Intrusion (Percentage increase w.r.t ODB56) | | | |
| 1 | Peak steering column intrusion X (mm) | | +10 |
| 2 | Peak A pillar (Top) intrusion X (mm) | | -3 |

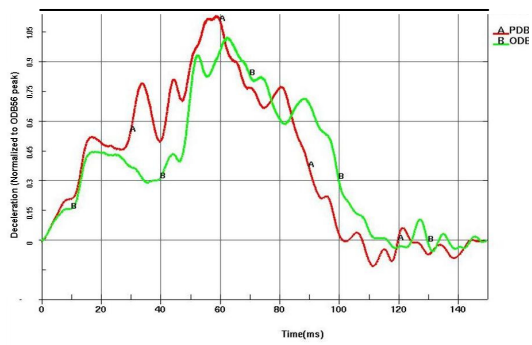


**Figure 9. ODB56 Vs PDB60 crash pulse comparison for small car.**

The Effect of replacing ODB56 with PDB60 on mid sized cars is summarized below.

- Overall deformation of vehicles structure increased.
- Resulting pulse is stiffer
- Resulting intrusions are higher

The crash pulse and the intrusion show that the crash severity of PDB on mid sized cars is less than the small cars.

From the results of 1100 kg car it was observed that the energy absorbed by vehicle with PDB60 has been increased by 14.3 kJ and 46 kJ respectively. In order to get similar vehicle intrusion with PDB, the vehicle stiffness has to be improved.

**SUV with 2400 kg kerb weight**

The effect on structural crash performance of SUVs by replacing the ODB56 by PDB60 is given in the Table 3. The crash pulse comparison is shown in Figure10.

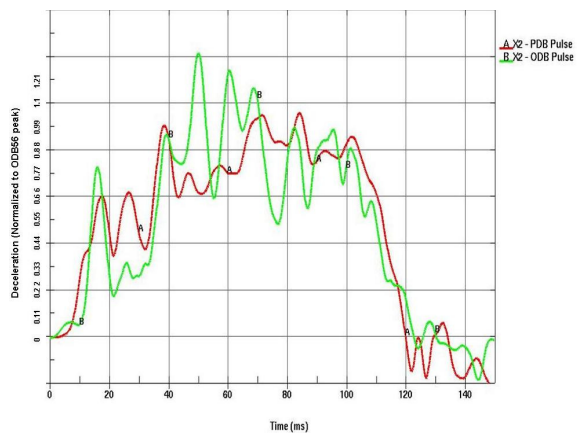


**Figure10. ODB56 Vs PDB60 crash pulse comparison for SUV.**

**Table 3. ODB56 VS PDB60 result comparison for SUV.**

| Sr. no | Description | ODB 56 | PDB 60 |
|---|---|---|---|
| 1 | Initial Kinetic Energy (kJ) | 285 | 329 |
| 2 | Energy absorbed by the vehicle (kJ) | 147 | 94.8 |
| 3 | Energy absorbed by the barrier (kJ) | 93.5 | 209 |
| 4 | Residual kinetic energy (kJ) | 19.2 | 14.5 |
| 5 | Energy lost in Friction and Miscellaneous Energy (kJ) | 25.3 | 10.7 |
| 6 | Stopping distance X (mm) | 930.9 | 1014.9 |
| 7 | Time to zero X velocity (ms) | 98.7 | 102.5 |
| Intrusion (Percentage change w.r.t ODB56) | | | |
| 1 | Peak steering column intrusion X | | -87 |
| 2 | Peak A pillar (Top) X-intrusion | | -90 |

The Effect of replacing ODB56 with PDB60 on SUVs cars is summarized below.

- Overall deformation of vehicles structure reduced.
- Resulting pulse is softer
- Resulting intrusions are lower

The crash pulse and the intrusion show that the crash severity of PDB60 on SUVs is lower than ODB56.

For vehicles that meet ODB56 test requirements, it is observed that impact of higher stiffness of PDB reduces with increasing mass of the vehicle. This is primarily because ODB56 forces the vehicle structure energy absorption capacity to be proportional to the mass.

The graph in Figure 11 shows the vehicle stiffness for 40 percentage of the barrier overlap for ODB56 case.
It was also observed from the simulations that PDB has higher energy absorbing capacity than ODB. It is possible for a stiffer vehicle to meet the PDB60 requirements without any energy absorbing zone at the front.

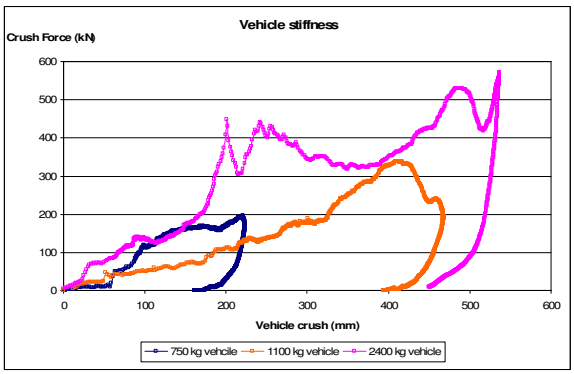


**Figure 11. Vehicle stiffness with 40 % overlap.**

To study this, simulations were carried out on a vehicle having stiff front end structure.
For this stiff vehicle the vehicle front end stiffness is further increased (over stiff) and one more PDB60 simulation is carried out. The results of these simulations are given in Figure 12 and Table 4.

**Table 4. Comparison of ODB56, PDB60 simulation results for vehicles with stiff and over stiff front end.**

| Sr. No | Description | ODB56 (STIFF vehicle) | PDB60 (STIFF vehicle) | PDB60 (OVER STIFF vehicle) |
|---|---|---|---|---|
| 1 | Initial Kinetic Energy (kJ) | 177 | 189 | 192 |
| **2** | **Energy absorbed by the vehicle (kJ)** | **60** | **48** | **45** |
| **3** | **Energy absorbed by the barrier (kJ)** | **80** | **116** | **122** |
| 4 | Residual kinetic energy (kJ) | 14 | 7 | 9 |
| 5 | Energy lost in Friction and Miscellaneous Energy (kJ) | 23 | 18 | 16 |
| 6 | Stopping distance X (mm) | 811 | 733 | 725 |
| 7 | Time to zero X velocity (ms) | 86 | 77 | 76 |
| Intrusion (Percentage change w.r.t ODB56 ) | | | | |
| 1 | Peak steering column intrusion X | | -35 | -58 |
| 2 | Peak A pillar (Top) X-intrusion | | -42 | -48 |

The intrusion and the crash pulse for the above simulations show that for a vehicle with stiff front end the severity of PDB60 is less than ODB56. Even with further increase in the vehicle front stiffness it can meet the requirements in PDB60 test.

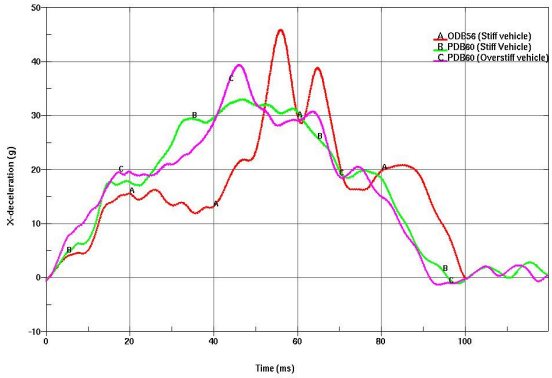


**Figure 12. Comparison of crash pulse of ODB56, PDB60 simulation results for vehicles with stiff and over stiff front end.**

## CONCLUSIONS:

- The study showed that PDB has higher energy absorption capacity than ODB.
- Due to higher energy absorption capacity of the PDB, it is possible to engineer a vehicle structure with reduced energy absorption capacity while still meeting the requirements with PDB.

## REFERENCES:


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