Crashworthiness

> What is crashworthiness?

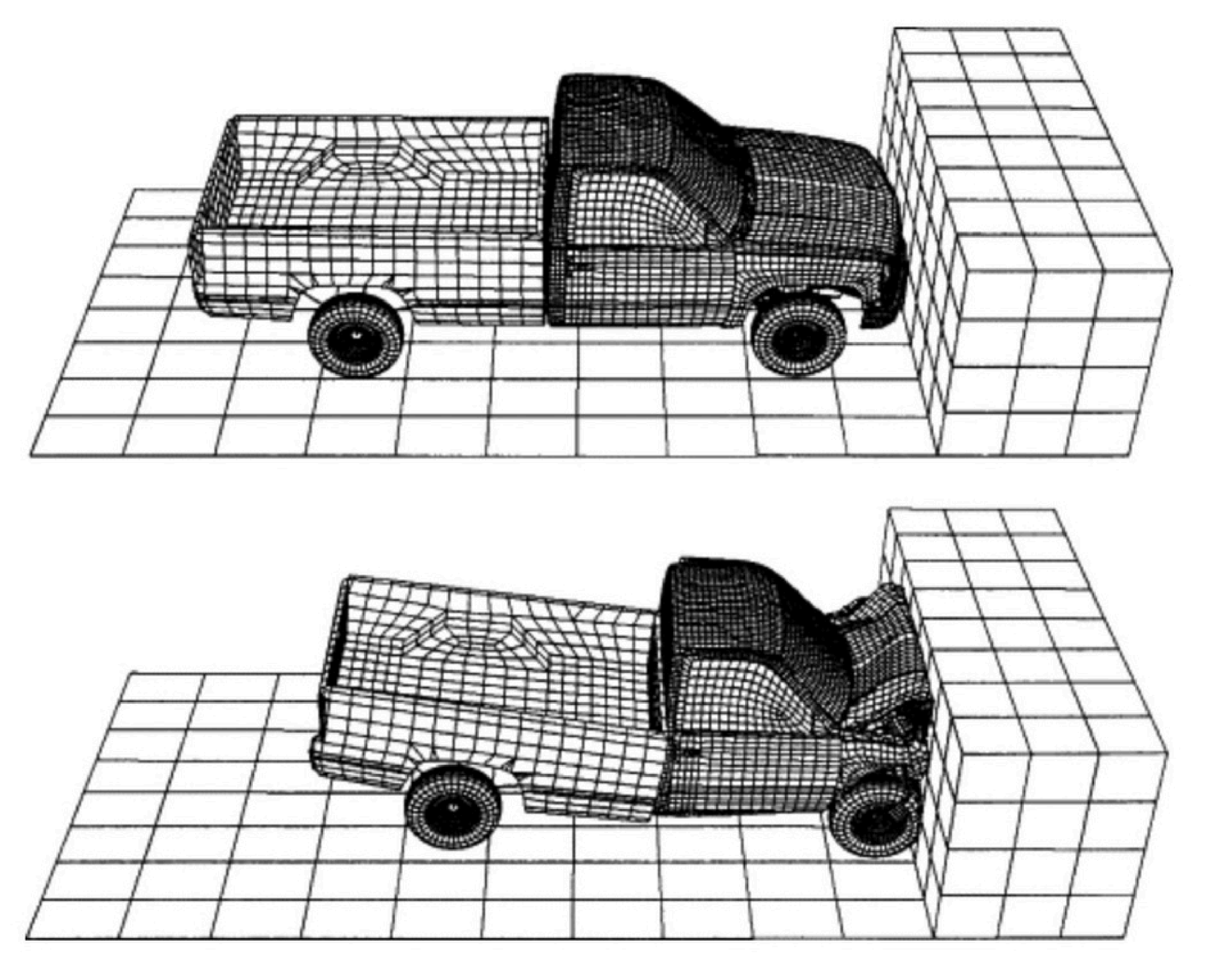
> What are the goals to be achieved?

Absorb crash kinetic energy, sufficient stiffness in bending and torsion.

Ultimate goal is to reduce harm for the occupant.

> Crashworthiness tests?

1. Component tests
2. Sled tests (Evaluates the performance of restraint systems)
3. Full scale barrier impacts.



Vehicle structure

Body on Frame

Body in white of a Unibody construction

Simulation Introduction

Four types of finite element model (FEM) to simulate the collision process.

1. Lumped parameter models: Analysis using lumped mass and non linear springs
2. Multibody models
3. Detailed FEM’s: Meshed by plate or shell elements
4. Frame models used thin-walled beams (TWBs) and plastic joints

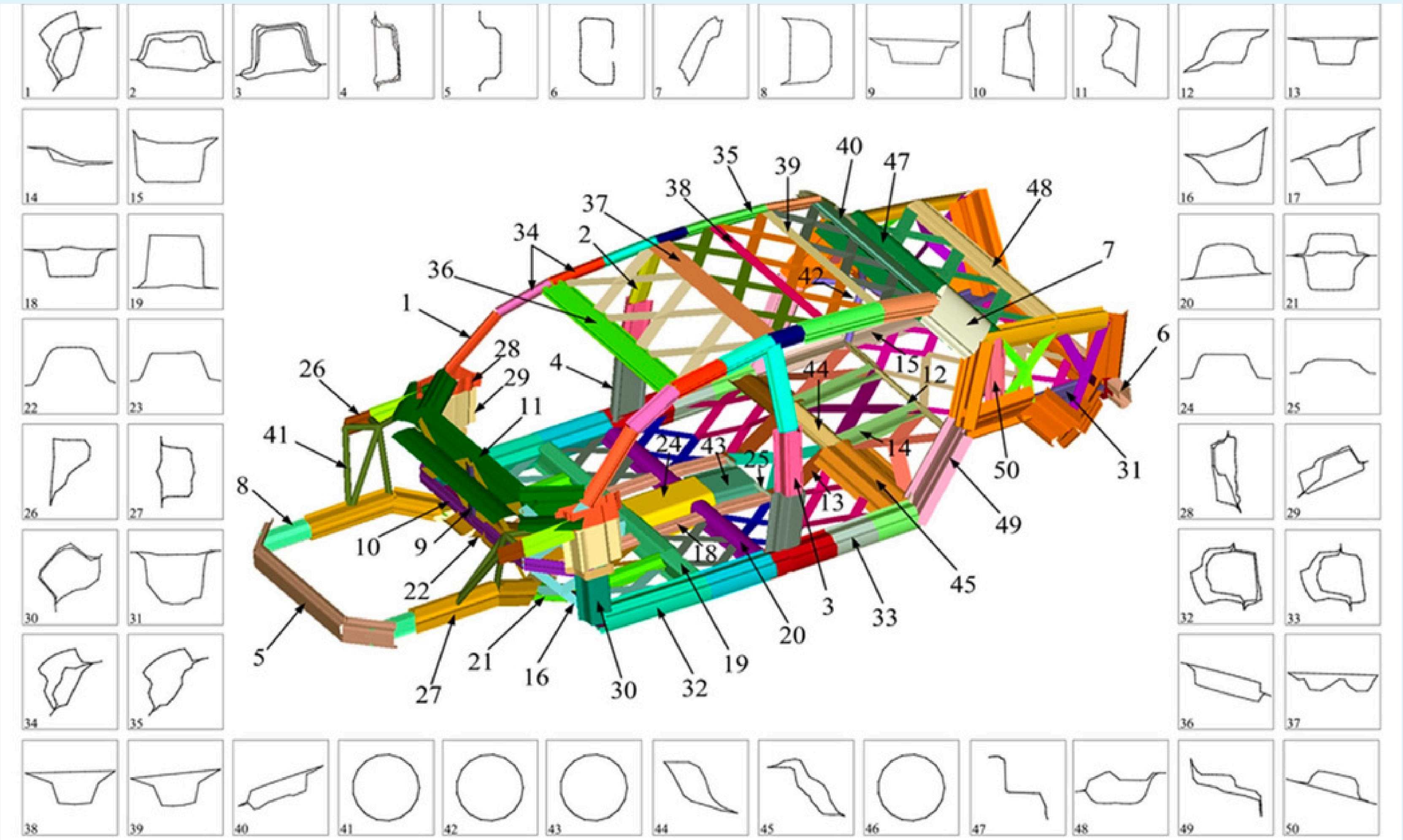


Fig. 1. Automotive frame of TWBs with complex cross-sectional shape.

FEM of automotive frame

During the collision process, the plastic deformation occurs at the joint.

Torsional moment of inertia:

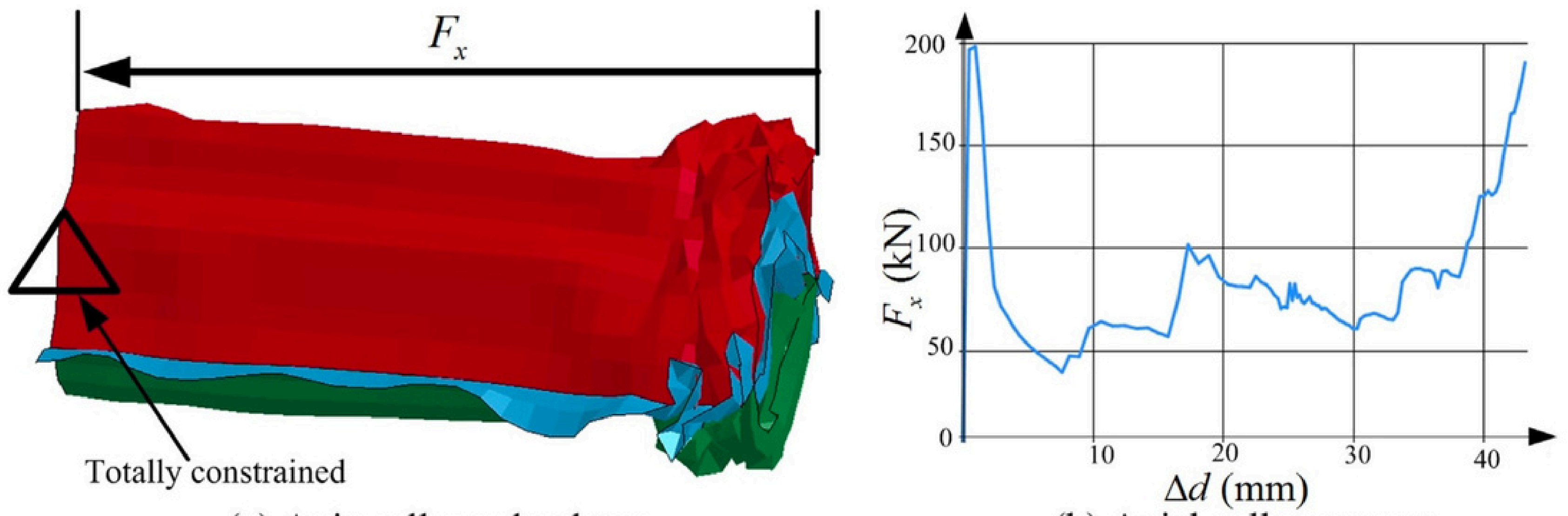
$$J_4^c = 4(q_1F_1 + q_2F_2 + q_3F_3 + q_4F_4)$$

where q_1, q_2, q_3 and q_4 are solved by Eq. (13)

$$\begin{bmatrix} \frac{L_u}{t_u} + \frac{L_{r1}}{t_{r1}} + \frac{L_m - L'_m}{t_m} & -\frac{L_{r1}}{t_{r1}} & -\frac{L_m - L'_m}{t_m} & 0 \\ -\frac{L_{r1}}{t_{r1}} & \frac{L_{r1}}{t_{r1}} + \frac{L'_m}{t_m} & -\frac{L'_m}{t_m} & 0 \\ -\frac{L_m - L'_m}{t_m} & -\frac{L'_m}{t_m} & \frac{L_m}{t_m} + \frac{L_{r2}}{t_{r2}} & -\frac{L_{r2}}{t_{r2}} \\ 0 & 0 & -\frac{L_{r2}}{t_{r2}} & \frac{L_{r2}}{t_{r2}} + \frac{L_l}{t_l} \end{bmatrix} \begin{pmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \end{pmatrix} = \begin{pmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \end{pmatrix}$$

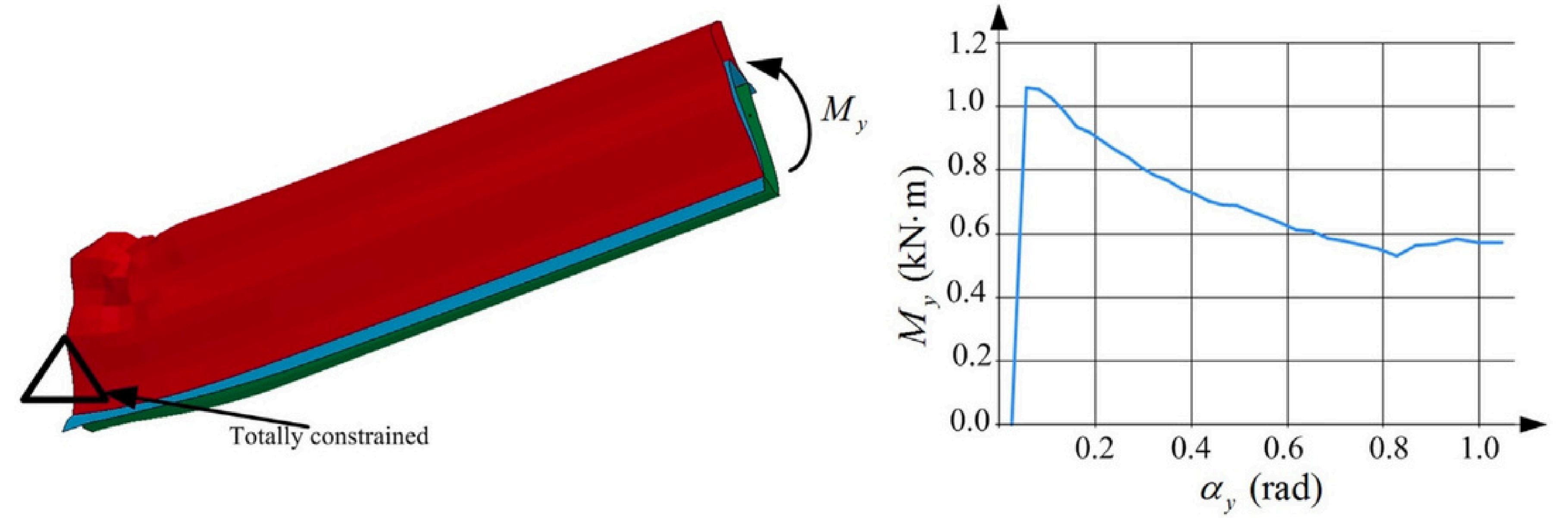
FEM of automotive frame

> Types of plastic deformation of TWB:

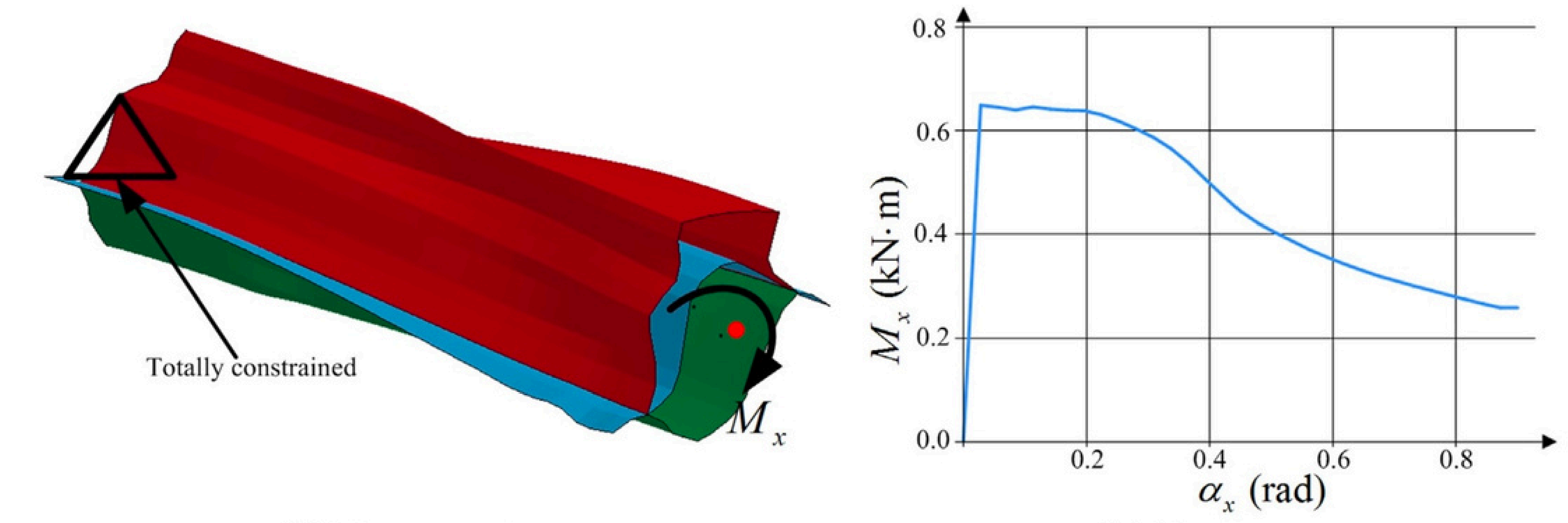


(a) Axis collapse loadstep (b) Axial collapse curve

Fig. 7. Axial collapse of plastic joint.



(a) Bending of y-axis loadstep (b) Bending of y-axis curve



(a) Torsion loadstep (b) Torsion curve

Fig. 9. Torsion of plastic joint around x-axis.

FEM of automotive frame

Thin walled straight beam:

Fig. 12. Thin-walled straight beam sample.

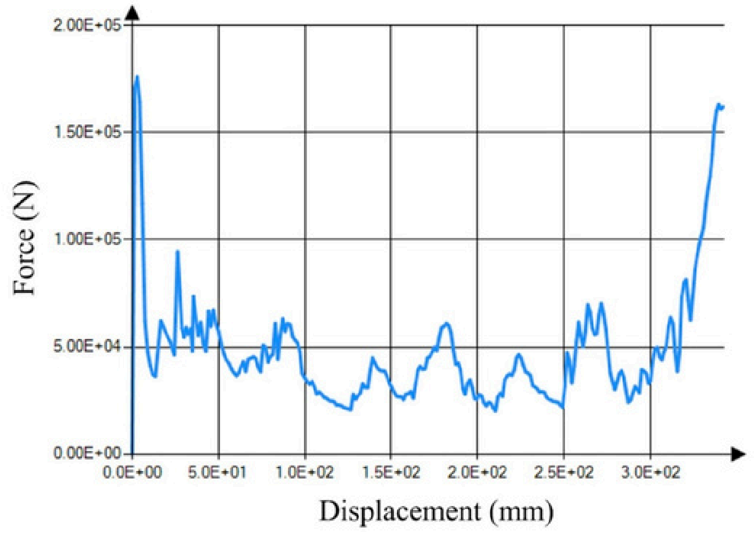


Fig. 13. Axial collision of plastic joint.

(a) Simplified beam (b) Detailed beam (c) Experiment

Fig. 14. Deformation of thin-walled straight beam.

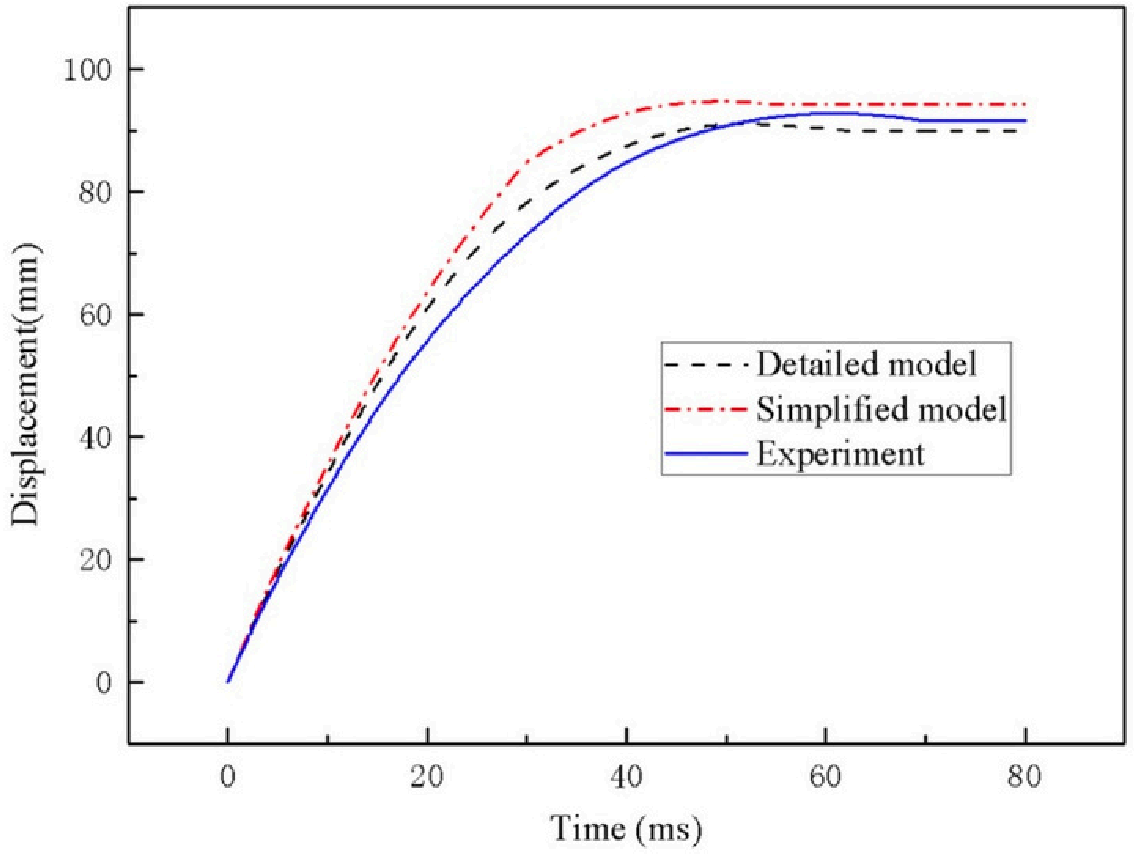


Fig. 15. Displacement of thin-walled straight beam.

FEM of automotive frame

Automotive frame:

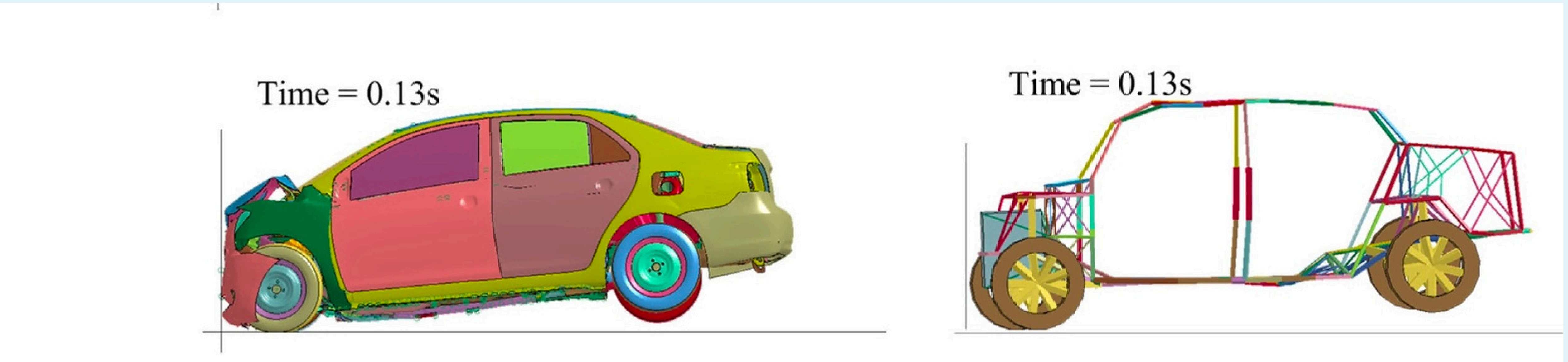


Fig. 21. Deformation process of automotive model.

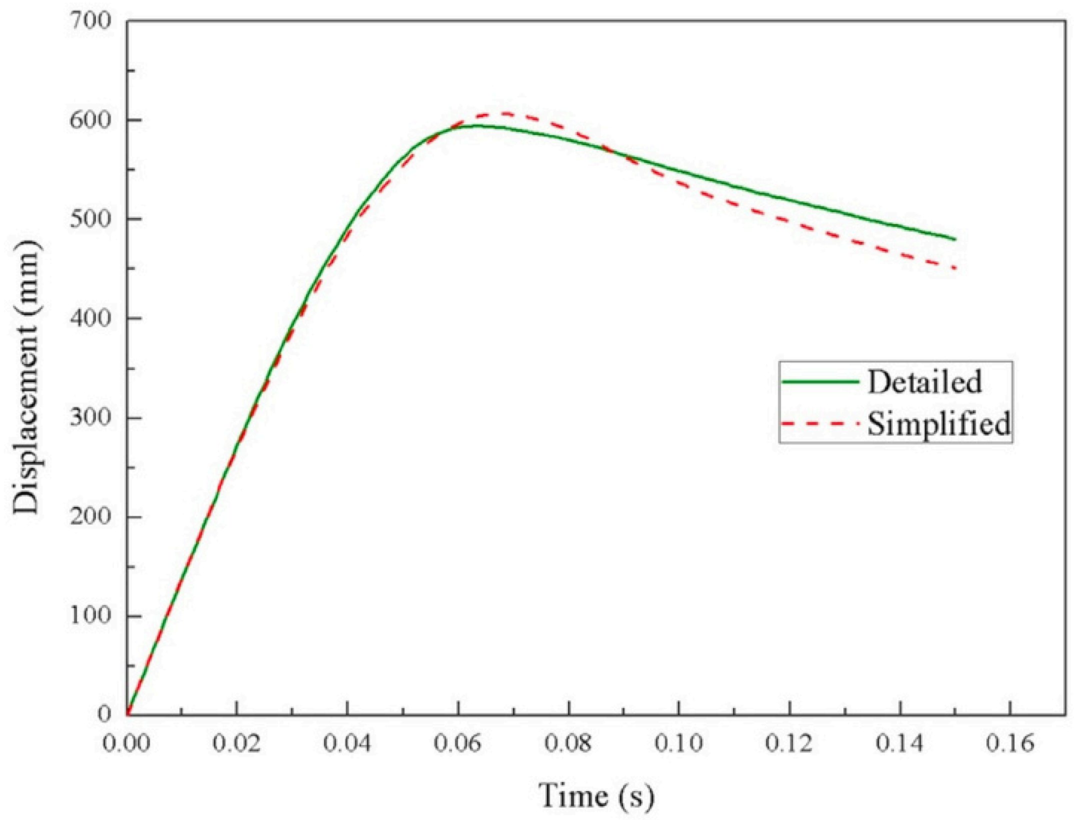


Fig. 22. Centroid displacement of automotive model.

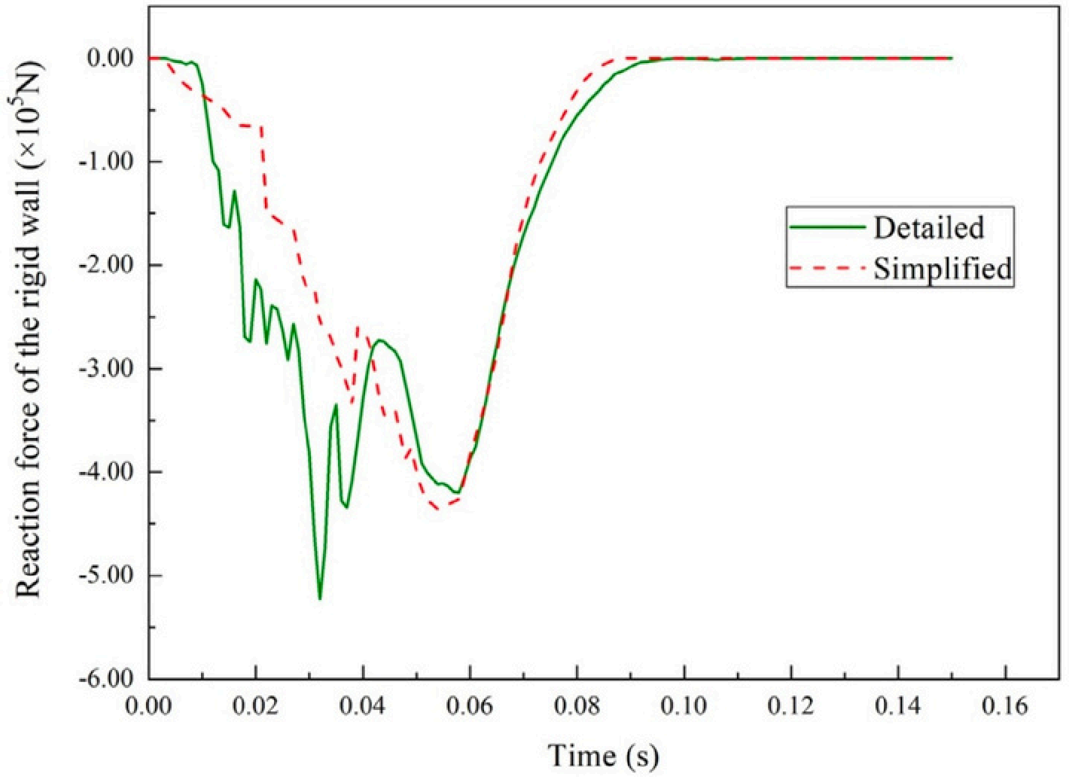


Fig. 23. Reaction force of the rigid wall of automotive model.

Conclusion

The deformation is basically the same for the thin wall beam method and the exact FEM method and the error can be controlled within 5%.

Comptutational cost is largely reduced

Especially for the automotive model, the computational cost is only 7 min, running on the laptop. Compared to the detailed FEM, the speed-up ratio is 289 times.

~Thank you~