

Unibody vs Body-on-Frame

Torsional and bending rigidity, architecture trade-offs and an FEA stiffness case study

Key Terms

Unibody	Body and frame welded into one load-bearing structure (body-frame integral). Standard on cars, crossovers and minivans.
Body-on-frame	Separate frame with the body bolted on; trucks and heavy-duty SUVs.
Torsional rigidity	Torque needed to twist the body one degree. Higher = solid feel, fewer squeaks and rattles.
Bending rigidity	Resistance to sag under vertical load; less critical than torsion.
Modulus of rigidity	$G = \text{shear stress} / \text{shear strain}$.
Vehicle platform	Shared architecture and hardpoints reused across models; crossovers ride on car platforms.

Stress & Stiffness (standard relations)

Bending stress	$\sigma = M c / I$	Max at the outer fiber, farthest from the neutral axis.
Torsional shear	$\tau = T r / J$	$J = \text{polar moment of inertia}$.
Twist angle	$\theta = T L / (G J)$	Torsional stiffness $k_t = T / \theta$.
Modulus of rigidity	$G = \tau / \gamma$	

Unibody vs Body-on-Frame

	Unibody	Body-on-frame
Mass / fuel economy	Lighter / better	Heavier / worse
Ride & handling	Better	Less refined
Crash energy	Integrated crush zones	Separate crush structure
Towing / off-road / clearance	Lower	Higher
Repair after severe crash	Harder, costlier	Easier

Honda Ridgeline unibody: 2.5× bending and 20× torsional rigidity vs conventional BOF (Honda). Cadillac CT6 unibody joins 13 materials.

FEA Case Study (HyperMesh / OptiStruct, aluminum unibody)

Item	Value
Bending load case	1,000 N on each rocker at H-point (212 mm ahead of B-pillar); shock towers fixed
Torsion load case	1,356,000 N-mm couple at front shock towers; rear towers fixed
Front header	40 × 20 mm → 78.82 × 29.66 mm (3 mm wall kept)
B-pillar	39.67 × 19.80 mm → 89.74 × 39.66 mm (3.8 mm wall kept)
Added roof bow	69.22 × 39.26 mm, 1.8 mm, above B-pillar
Mass	64.72 kg → 70.12 kg (+8.35%) → 66.26 kg after down-gauging rear to 1.5 mm (+2.3%)
Result (trial 2)	Bending stiffness +6%, torsional stiffness +29% (target ≥ 5%)

Takeaways

- Bigger B-pillar section engages the roof rail as a primary load path.
- A roof bow over the B-pillar transfers load side to side and keeps rails from moving inboard.
- Down-gauge lightly loaded areas (the rear here) to recover mass.
- Next steps: grow rocker, roof rail and A-pillar sections, then cut gauges to ≤ 2 mm and add mass only where needed.