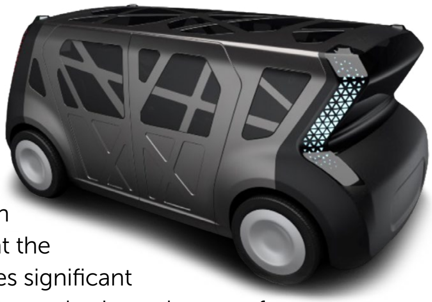
Steel E-Motive
Shaping the Future of Sustainable Transportation ISSUE 2
Technical Microstudies Highlighting Design and Performance Innovations for Steel E-Motive

Steel E-Motive's Body Structure Concepts Meet Stringent Side Crash Requirements



INTRODUCTION

Urbanization and Net Zero Emissions targets are key contributors to the transportation shift to mobility on demand in densely populated urban environments. It's here that the mobility industry anticipates significant growth in ride sharing, with emphasis on the use of autonomous vehicle technologies and electrification to achieve that goal.

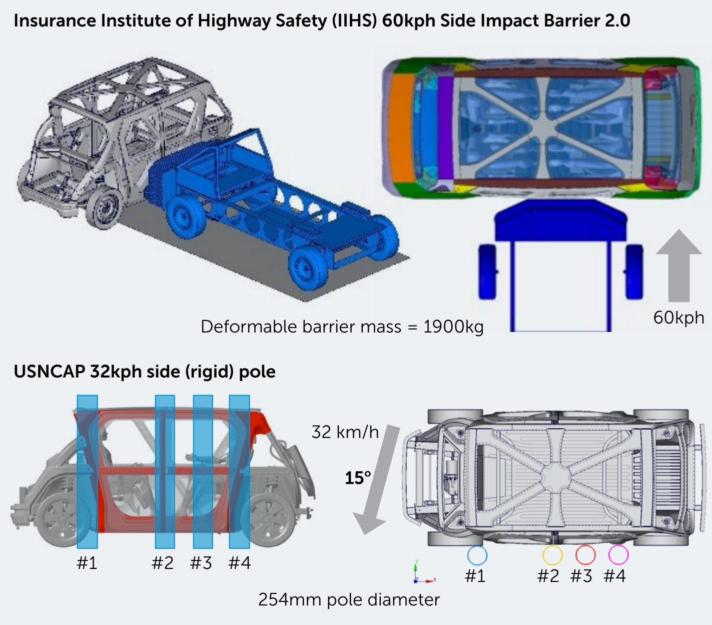
WorldAutoSteel's Steel E-Motive (SEM) program demonstrates autonomous ride-sharing concepts that maximize occupancy and comfort through unique seating configurations and easy vehicle access, while offering a clear path to Net Zero.

These vehicles were developed for mixed-mode traffic conditions, so the structures must comply to the latest global high-speed crashworthiness requirements. The protection of the vehicle and its occupants in a side impact collision is particularly challenging due to the relatively small space and distance between the collision location and the occupants. The propulsion battery can also be particularly vulnerable in a side collision event due to its size and position within the vehicle floor zone. Rupture of the battery cells in a crash event can result in electrolyte leakage, which can subsequently lead to a "thermal runaway" event, a potentially hazardous situation where a fire and release of toxic gases and fumes can occur.

These risks can be mitigated by appropriate design of the body structure, coupled with the latest Advanced High Strength Steel (AHSS) grades, providing both crash energy absorption and intrusion protection in a very small space. This report details Steel E-Motive side crash results.

SIDE CRASH PROTECTION LOAD CASES AND STRATEGIES

Standardised crash load cases help to develop and verify vehicle structural performance, designed to replicate real-world collision scenarios. The SEM engineering team selected two global industry standards to develop and ensure appropriate side crash performance: IIHS and USNCAP Side Crash, which are described below in Figure 1.



The IIHS side barrier 2.0 load case replicates a vehicle-to-vehicle collision, with the impact vehicle striking the target vehicle at 90 degrees/perpendicular. The IIHS side crash deformable impact barrier is representative of a typical mid-size sport utility vehicle. The frontal profile and alignment of the barrier result in the side doors of the impacted vehicle withstanding a majority of the initial collision. The lower edge of the impact barrier is slightly higher than the Steel E-Motive body structure rocker and battery zone; therefore, there is a lower risk of damage to the battery for this load case. The side barrier crash loads are managed by appropriate design of the side doors and supporting body structure.

The side crash performance targets from IIHS feature structural intrusion values that result in low occupant injury levels. These intrusion values were calculated using Finite Element Analysis (FEA) crash simulation models. The highest safety rating ("good") for the IIHS test is achieved when there is clearance greater than 180mm between the crash deformed structure and the centre line of the occupants (test dummy).

The USNCAP 64kph side pole test simulates a vehicle striking a stationary object, such as a bollard or lamppost at a high lateral speed. This test is particularly challenging due to the small impact zone (254mm diameter pole) and the impact covering the complete height of the vehicle, resulting in the body structure managing a relatively concentrated impact load. The USNCAP 64kph test protocol is replicated and applied by many other global crash tests. The standard test is targeted for the protection of the front seat occupants; therefore, the pole is aligned to the front occupant (test dummy) head location (Location 1) shown in the image.

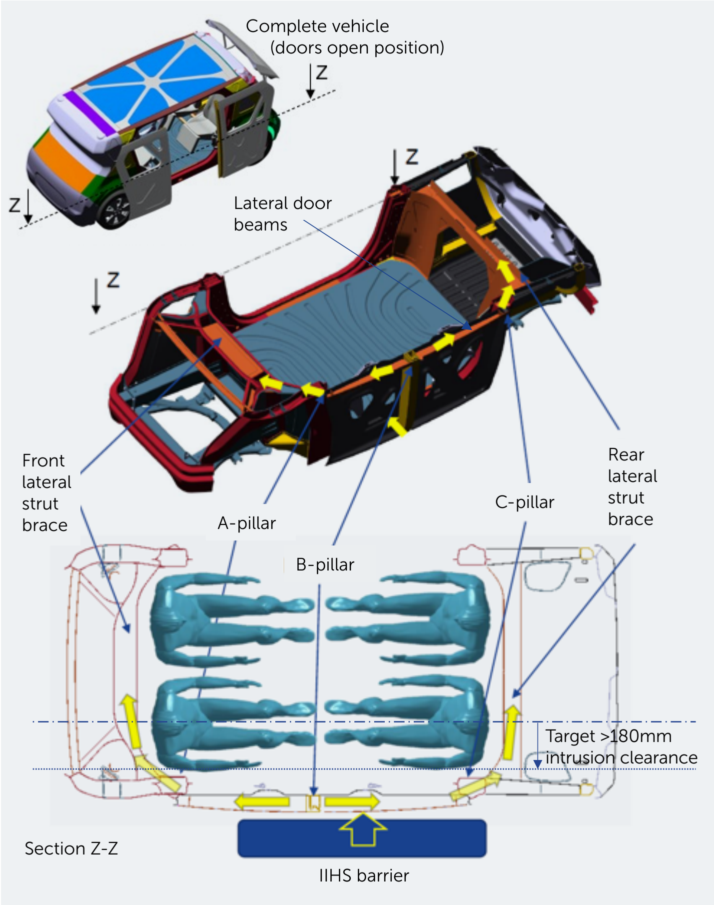
Due to the severe nature and concentrated crash load, there is also significant risk of damage to the propulsion battery. To mitigate this risk, the SEM engineering team considered and engineered for additional pole impact locations. For example, positions 2 and 4 are the worst-case locations for protection of the battery due to the relative locations of the floor structural cross members and the battery modules. Position 3 is in line with the rear occupant's head, so the design and materials that are relevant for position 1 are equally important here to ensure that the rear occupants receive the same level of protection as the front occupants. This "due diligence" approach of considering additional side pole impact locations is a common practice applied by vehicle manufacturers.

The USNCAP pole test assessment is based solely on occupant injury levels, calculated from the measured forces acting on the crash test dummies. Simulation dummies were not included in the Steel E-Motive FEA calculations; therefore, we applied the IIHS >180mm clearance targets for the USNCAP load cases. Engineers ensured protection of the propulsion battery by applying a target of >25mm static intrusion clearance between the body structure (usually the rocker inner panel) and the battery module. This clearance ensures that battery modules are not contacted (dynamically) during the crash events. These targets were applied for all four side pole load cases.

Achieving side crashworthiness requires appropriate management of the crash energy and impact forces. Thoughtful design of the body structure and appropriate selection of specific AHSS grades are the keys to protecting occupants and the propulsion battery.

The Steel E-Motive concept features an open body-in-white (BIW) structure, with A- and C-pillar mounted hinged "scissor" doors, creating a wide door aperture for enhanced occupant ingress and egress. The structural B-pillar is housed within these scissor doors. The B-pillars and the lateral door beams provide the primary load reaction for the IIHS side barrier load case. The crash loads are then distributed into the body structure via the A- and C-pillars. The front and rear lateral strut braces provide secondary load paths and reaction to the crash loads. These structures combine to form a "belt line" hoop around the front and rear occupants. The B-pillar overlaps the lower rocker and upper cant rail structures, providing further crash load distribution and paths into the body structure. These design features are illustrated in Figure 2.

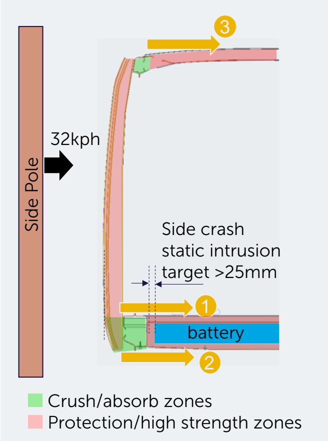
Figure 2: Steel E-Motive body structure features that contribute to superior crash performance



For the USNCAP 64kph side pole load case, the protection of the front- and rear-seated occupants is assured by a similar load path strategy to the IIHS side barrier. The body structure A- and C-pillars are aligned to the torso and head of the occupants. This provides a direct load path and interface for the barrier to vehicle for the critical side pole test locations 1 and 3. The protection of the propulsion battery for side pole test locations 2 and 4 adopt a different load path strategy.

"Crushable" zones (shown in green in the image to the right) provide some energy-absorbing capacity, analogous to typical front and rear crash crumple zones, albeit on a smaller scale. The high strength protection zone around the propulsion battery provides appropriate protection. The floor structure provides an upper load path (1), the battery bottom cover, and a lower load path (2), and an ultra-high strength steel rocker inner panel helps to minimise deformation of the body structure and contact with the battery modules. Additionally, the upper cant rail and roof structure (load path 3) provide some energy absorption and load path management (see Figure 3).

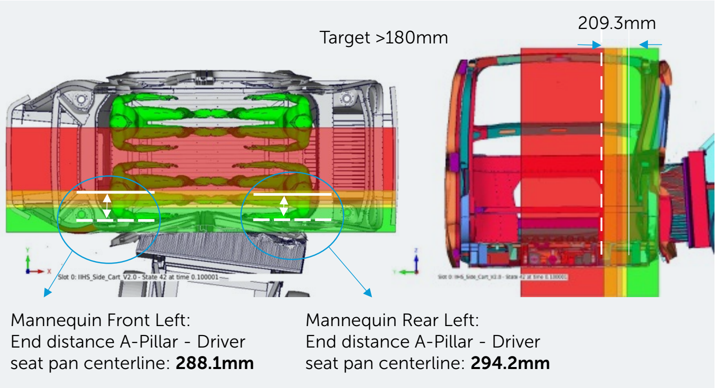
Figure 3: Side pole battery protection and load paths



SEM SIDE CRASH PERFORMANCE RESULTS

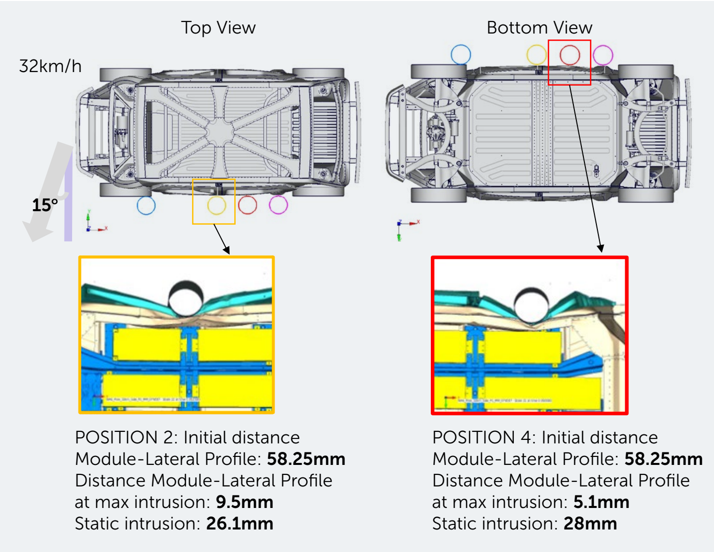
FEA simulations drove the development and demonstration of Steel E-Motive's side crash performance. The predicted performance of the IIHS side barrier load cases achieved a highest "good" rating, as the intrusion clearance from the centre line of the front and rear occupant were predicted to be greater than 180mm, as shown in Figure 4 below.

Figure 4: IIHS 60kph side barrier, simulation results



The FEA simulation results for the USNCAP side pole test demonstrated that the front and rear occupants remained protected, with >180mm intrusion clearance achieved. The protection of the propulsion battery was assured by the static (post-test) intrusion values achieving the >25mm target in the battery compartment, as shown below. Dynamically (during the crash event), the structural intrusion levels of the body structure are sufficiently low (~5mm) such that there is no contact with the battery modules. This means that there is a very low risk of rupture and damage to the battery modules and cells for the side pole test locations, as shown below in Figure 5.

Figure 5: USNCAP 64kph side (rigid) pole simulation results



AHSS APPLICATIONS

For the IIHS side barrier load case, hydroformed B-pillar tubes manage the initial impact loads. The CR400Y690T-RA ("TRIP690") grade enables the closed geometric profile whilst providing high strength, distributing loads into the upper cant rail and rocker/floor regions. The horizontal door beams feature a roll-stamped CR1200Y1470T-MS grade, helping to minimise crush intrusion, and distribute loads into the A- and C-pillars. The A-pillars are Press Hardened Steel (PHS) with 1900MPa Ultimate Tensile Strength (UTS), while the rear C-pillars utilize PHS 1500MPa UTS. The ultra-high strength properties of these AHSS grades enable lower material gauge thicknesses to be applied, contributing to low overall BIW weight and fewer material production emissions.

Figure 6: AHSS steel grades for the IIHS side barrier crash management

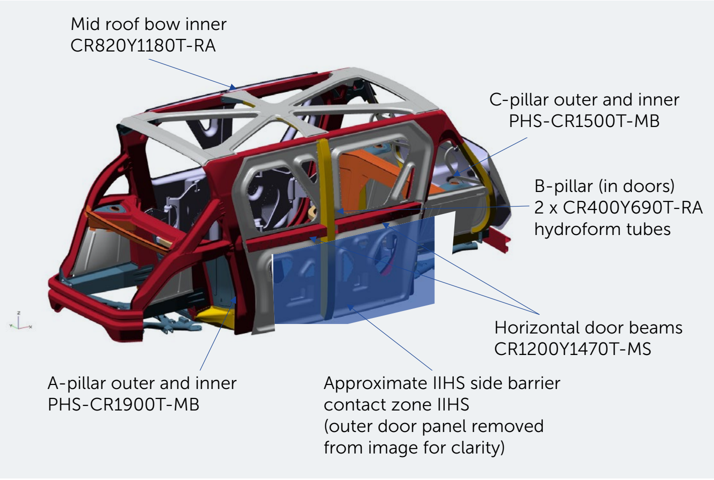
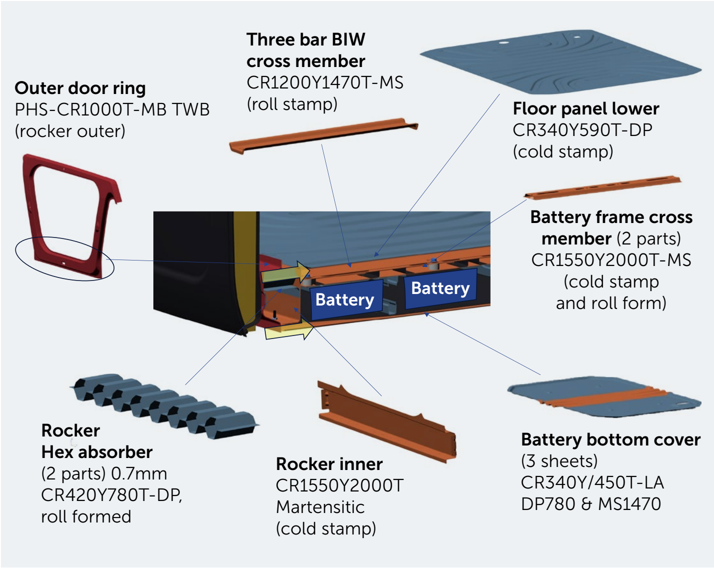


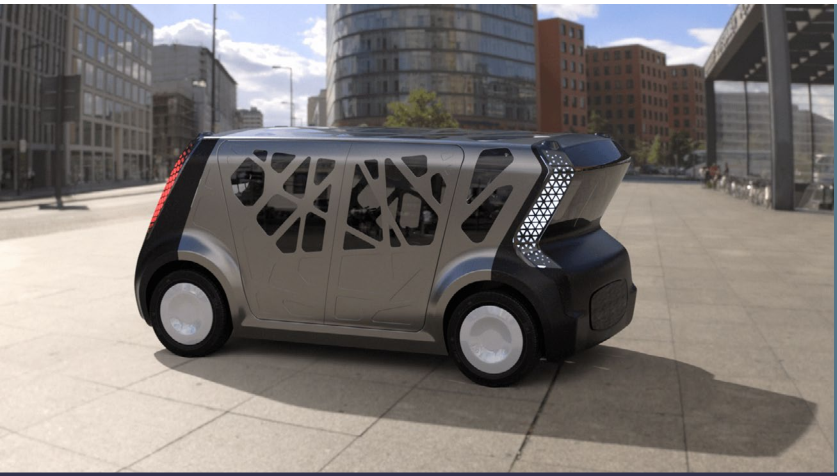
Table 1: Advanced high strength steel (AHSS) applications for Steel E-Motive side crash performance

Steel Grade (MPa, UTS)	Component	Steel Grade (MPa, UTS)	Component
Trip 690	Hydroformed B-Pillar	MS 1470	Horizontal door beams
PHS 1900	A-Pillar	PHS 1500	C-Pillar
PHS 1000	Upper, lower sections of TWB door ring	DP 780	Rocker hex absorption beams
MS 1470	Floor cross members	MS 2000	Battery carrier frame cross members
MS 1470	Centre stamping of 3-piece TWB battery bottom cover		

The protection of the battery for the USNCAP rigid side pole load case is achieved by the combination of the absorption/crushable and ultra-high strength members. The rocker hex absorber component comprises two roll-formed Dual Phase (DP) 780 sheets, joined to form hexagonal tube profiles perpendicular to the rigid pole impact. The hexagonal profiles and Dual Phase AHSS provide very good energy absorption characteristics. The upper protection load path comprises Martensitic grade floor cross members (CR1200Y1470T-MS) which are bolted to the battery frame cross members (CR1550Y2000T-MS). This combination provides a very high strength lateral load path, reacting the crash loads and minimising intrusion. Similarly, the battery bottom cover is cold stamped from CR340Y450-LA, DP780 and features a MS1470 centre Tailor Welded Blank (TWB) which provides the high strength lower load path. The SEM engineering team was able to minimize gauge thickness due to the ultra-high strength material properties. These applications are summarised in the above table and in Figures 6 and 7.

Figure 7: AHSS applications for IIHS side pole crash performance





CONCLUSION

The combined design approach and application of ultra-high strength, formable AHSS grades enable the Steel E-Motive body structure to achieve the highest ratings for side crashworthiness performance. Challenged by its open one-box design, unique side door configuration and compact size, SEM simulation results have the potential to achieve the IIHS "good" rating. Additionally, there is no contact between the deformed body structure and the battery modules, which lowers risk of battery module failure or rupture and mitigates the likelihood of battery electrolyte leakage and potentially dangerous thermal events.

For additional details on the Steel E-Motive project, including specific design and simulation results, visit **steelemotive.world/resources**