12. Summary of Phase 2 Results

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The Phase 2 of the ULSAB program has come to its conclusion with the build of the demonstration hardware.

The test results of the demonstration hardware are remarkable.

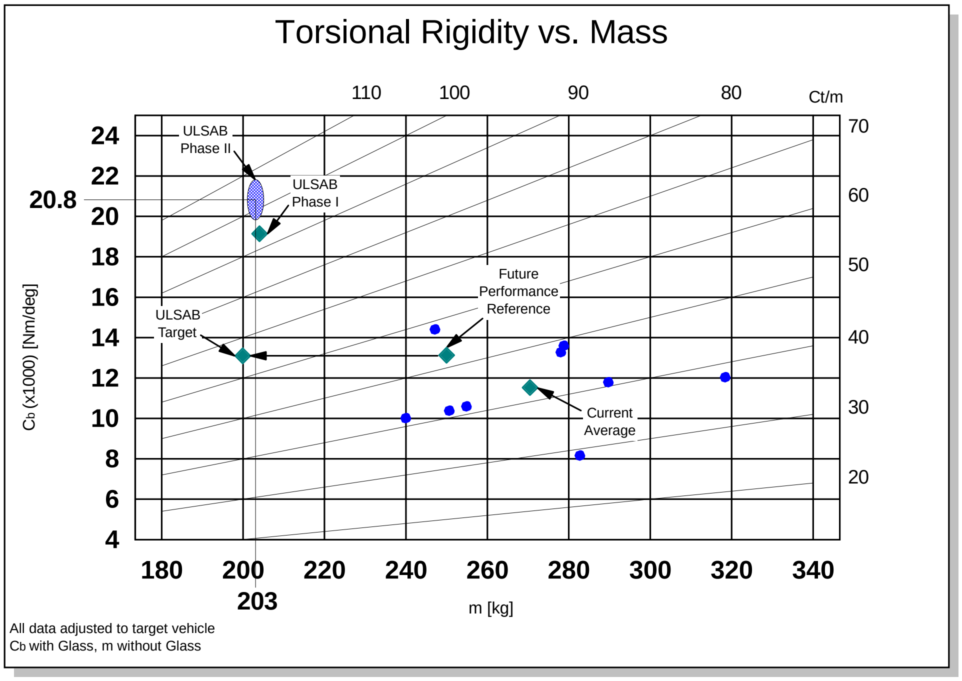
Performance		Phase 2 Results	Benchmark Average	Difference	Difference (%)
Mass	(kg)	**203**	**271**	- 68	- 25%
Static Torsional Rigidity	(Nm/deg)	**20800**	**11531**	+ 9269	+ 80%
Static Bending Rigidity	(N/mm)	**18100**	**11902**	+6198	+ 52%
First Body Structure Mode	(Hz)	**60**	**38**	+ 22	+ 58%

Figure 12-1 Structural Performance Summary

Relative to the benchmark average vehicle mass of 271 kg, the mass reduction achieved is 68 kg (25%).

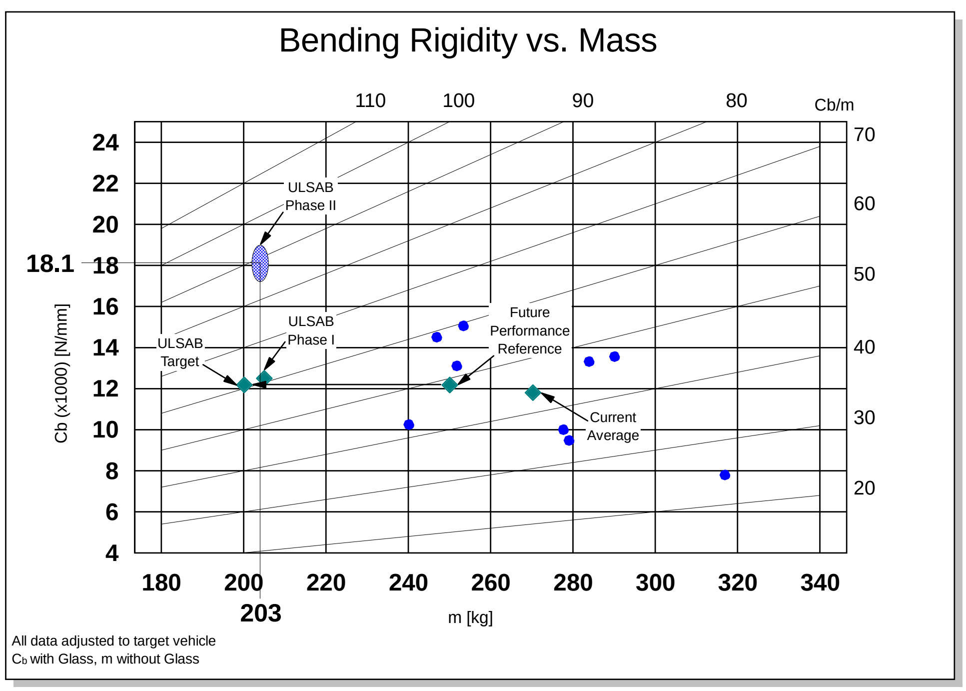
The static torsional rigidity exceeds the target. The efficiency (rigidity / mass) has increased, in relation to Phase 1, to 102.5 [(Nm/deg)/kg] (Fig. 12-2). The Phase 2 structural performance results are shown in the graphs as a tolerance field rather than a fixed point. To indicate that the mass and the performances can vary from one demonstration hardware structures to another, as it would also do in real mass production. The static bending rigidity as well as the first body structure mode have also been increased in comparison to the Phase 1 results (Fig. 12-3 and 12-4).

These high levels of static and dynamic rigidity provide an excellent basis for a complete vehicle development in respect to its NVH behavior.



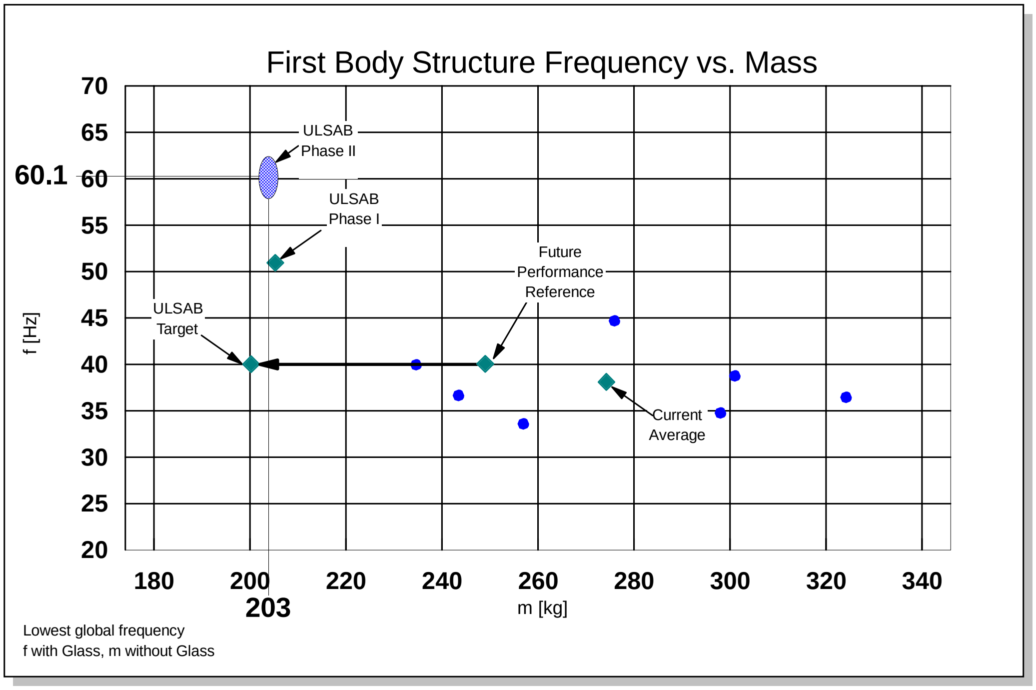
Reference Vehicles: Acura Legend, BMW 5 series, Chevrolet Lumina, Ford Taurus, Honda Accord, Lexus LS 400, Mazda 929, Mercedes Benz 190 E, Toyota Cressida

Figure. 12-2 ULSAB Phase 2 Torsional Efficiency



Reference Vehicles: Acura Legend, BMW 5 series, Chevrolet Lumina, Ford Taurus, Honda Accord, Lexus LS 400, Mazda 929, Mercedes Benz 190 E, Toyota Cressida

Figure. 12-3 ULSAB Phase 2 Bending Efficiency



Reference Vehicles: Acura Legend, Chevrolet Lumina, Ford Taurus, Honda Accord, Lexus LS 400, Mazda 929, Toyota Cressida

Figure. 12-4 ULSAB Phase 2 Frequency Efficiency

The results of the crash analysis confirmed the integrity and safety of the ULSAB structure. The AMS Offset Crash is considered one of the most severe crash tests of today. In recently performed comparison crash tests of AMS, with the same vehicle towards a deformable barrier with 40% offset at 64 km/h versus the AMS Offset Crash barrier with 50% offset at 55 km/n, the results were nearly equal. This confirms that the decision to analyze the ULSAB structure for its offset crash behavior using the AMS test configuration, determined at the beginning of Phase 2 in 1995, was the right choice.

The NCAP 100% Frontal Crash was run at 35 mph, 5 mph above the federal requirement of FMVSS 208, meaning 36% more energy had to be absorbed.

In both the 50% Offset and 100% Front Crash low footwell intrusion and structural integrity proved the safety of the structure.

The rear impact crash analysis, also run at 5 mph above the required speed of 30mph and showed fuel system integrity, passenger compartment integrity, residual volume and door opening after the analysis.

The side impact crash analysis showed good results for criteria, such as passenger compartment intrusion, B-Pillar displacements and overall shape of deformation.

The roof crash analysis proves that the roof meets the federal standard requirements and is stable and predictable.

The crash analysis was run with a vehicle crash mass of 1612 kg, meaning secondary weight savings of other components such as engine; suspension, etc. were not considered, to achieve a conservative approach.

Apart from the design of the structure and its optimized smooth load flow from front and rear rails into the rocker and the side roof rail concept; the use of high strength steels in 90% relative to the ULSAB structure mass was the key to achieve this crash performances at low mass.

This need to use high strength steel to achieve this crash performance with the given target for mass was a challenge for the part design and our suppliers.

Together with steel suppliers, part manufacturers, designers and engineers, the right materials were selected and the design was modified until it was feasible.

Significant mass reduction was also achieved with the use of tailor welded blanks in combination with high strength steel. The elimination of reinforcements and joints between parts reduced mass and enhanced crash and structural performance. Furthermore, the total number of parts and assembly steps was reduced. With the use of the tubular hydroforming manufacturing process for the side roof rail and sheet metal hydroforming for the roof panel, parts could be manufactured, contributing to performance and weight reduction. The hydroformed side roof rail made from a tube with a relatively large diameter of 96mm and a wall thickness of 1mm from high strength steel was made feasible in Phase 2.

The assembly sequence of the ULSAB structure with the body side inner subassembly, first assembled to the underbody structure and the body side outer in the following step, gives better weld access, especially in the rear of the structure. With this assembly sequence, weld access holes can be avoided and structural performance can be maintained.

Laser welding in assembly is successfully applied to weld the body side outer panel and the roof to the side roof rail. In addition, it was used to join the fender support rails and the front rails to enhance the performance.

In terms of the cost analysis, following extensive work in detail processing of components and assemblies, it was established that ULSAB would cost $947 to manufacture. The competitiveness of this cost is due to the design concept, which consolidated parts and eliminated many reinforcements, therefore saving stamping and welding operations.

These savings were partially offset by the cost of high strength steel and the new technologies such as laser welding and hydroforming, but the final conclusion of the analysis is that ULSAB can be produced without cost penalty.