MSEC-23

ASA Race Car Force Deflection Characteristics

Tom Gideon

General Motors - GM Racing

Chas Howe

Howe Racing Enterprises

ABSTRACT

Race car structure has been the subject of much discussion but little information. A hydraulic press has been constructed at Howe Racing to provide enough force to crush an ASA race car center section. This facility tests under quasi-static conditions that give a force deflection characteristic of an entire center section. The data can be used to make improvements in the strength or penetration resistance of a center section to improve driver safety. The data can also provide design guidance for energy absorbing elements that are added to the center section. This paper describes the results of that testing and preliminary design consideration for a replaceable energy absorber.

INTRODUCTION

The object of the testing described in this report was to determine the force deflection characteristics of the ASA center-section. The center-section of the ASA race car had evolved through many design iterations over the years. The goal of this evolution was to provide improved drivers safety. The center section (Figure 1) provides rollover protection to prevent collapse of the roof onto the driver. The door bars add strength to the structure and prevent penetration. A 3.175 mm (0.125inch) steel plate is bolted to the left side door bars to further improve penetration resistance.

The overall force deflection character of the center-section was unknown.

Further improvements in the structure, or additions of energy absorbing elements would require information on the strength of the 2004 center section design.

METHOD

The left side of the ASA chassis (Figure 1) was placed in fixture with force applied by a ram made up of a flat steel plate supported by steel beams and pushed by two hydraulic pistons.

The fixture supported the right side of the chassis uniformly by trusses to the right side of the shipping dock bay.

The purpose of the uniform loading on the right side was to spread the load without deflecting or damaging the right side. The loading of the chassis with this arrangement was as close to the inertial loading seen in car-to-wall left side impacts as possible.

RAM DESCRIPTION

Hydraulic Cylinders:
Cylinder Diameter: 66.7 mm (2.625 in)
Cylinder Stroke: 965 mm (8.0 in)
Hydraulic Pump: Greenlee Electric Mfg. No. 960
1.12 kW (1.5 hp)
Hydraulic Pump: Pressure Range 0 – 700 Bar
(0 – 10,000 psi)

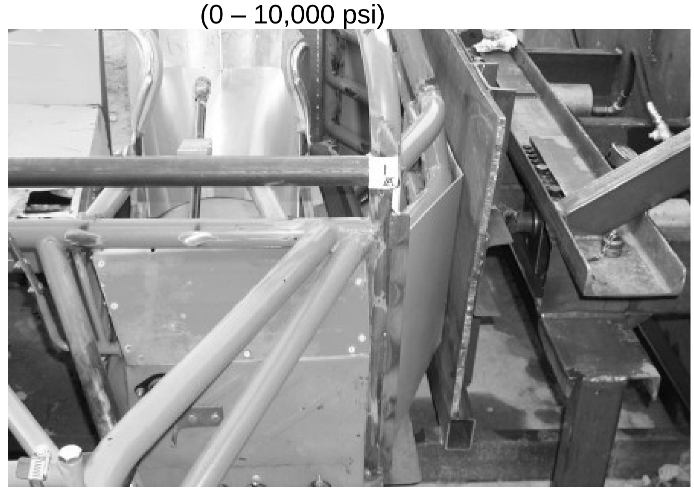

Figure 1

RESULTS

The force deflection curve of the left side of the ASA chassis is shown Figure 2.

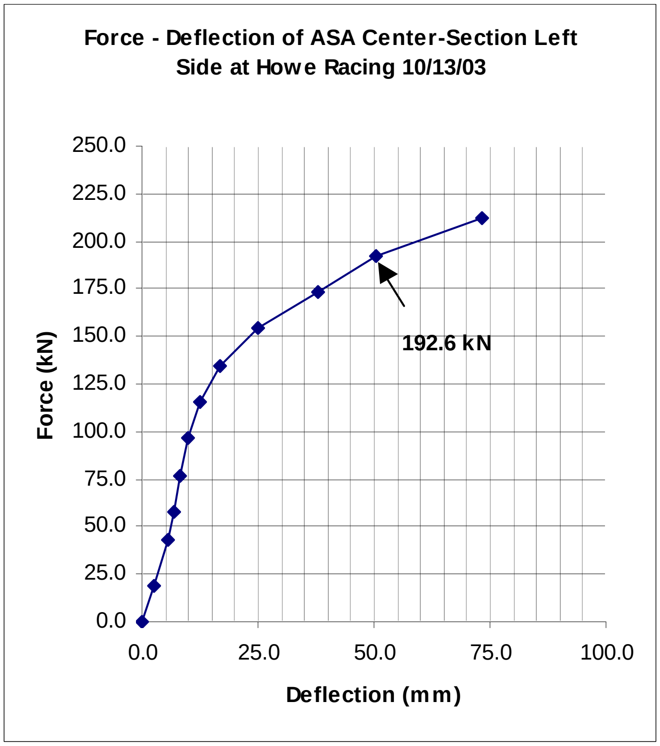

Figure 2

A force level of 192.5 kN (43,275#) shown in Figure 2 produced a deflection of 50.3 mm (1.98 inches) in the left side of the center section. When the chassis was unloaded from this force the chassis was still OK to use by replacing the door bars. The last force point obtained, 211.8 kN (47,625 #), permanently distorted the chassis and the testing was terminated.

Measurements were taken to see where deflection occurred. The measurements with a sketch of locations are shown in the Appendix Table 1 and Figure 5.

Pictures comparing the initial point and the final deflection point are shown the Appendix Figures 6 & 7.

DISCUSSION

This was a preliminary study to provide design guidance on present chassis strength. The strength measurements serve as baseline data for future center-section designs.

The support structure bearing on the right side of the chassis did accomplish the goal of uniform loading to the right side during the test. No distortion of the chassis was seen on the right side and all the crush observed occurred on the left side in a manner similar to a wall impact to the left side.

The chassis had been updated to the latest rules with an additional bar at the front of dash (Appendix Figure 8) and a plate behind the drivers seat to prevent intrusion (Appendix Figure 9).

A new center section design being developed (Howe, C.) has benefited from the information from this test. The design of the "A" post bracing was revised to eliminate the weakening in the cage caused by the deflection seen in Figure 3. The vent support bar in the next generation design was moved from the door bar to a point in the cage that did not distort in this test.

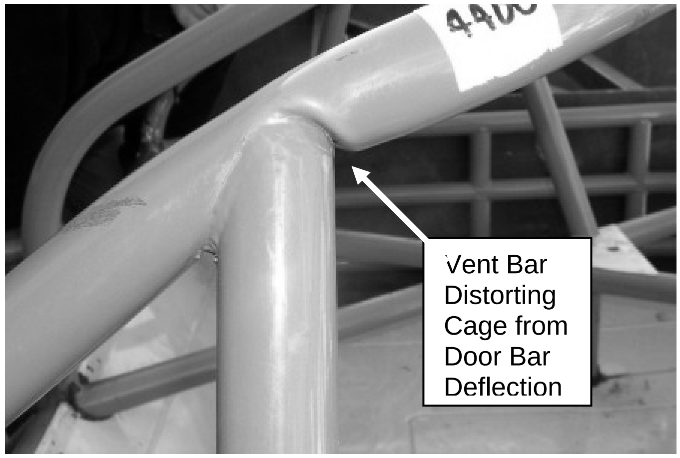

Figure 3

Energy Absorber Design:

The purpose of an add-on energy absorber is to create constant force deflection on impact that results in a predictable G load to the chassis. The constant force absorber can be replaced after minor incidents. The. The force predicted in the energy absorber design must be a lower value than the force necessary to distort the center section.

From the test results 192.5 kN (43,275#) force is the design limit above which the center section will be damaged.

For this example the force goal for the aluminum honeycomb absorber will be set to 186.8 kN (42,000#).

The area of the honeycomb multiplied by the crush strength of the honeycomb is set to the force goal.

The strength values for a commercial grade of aluminum honeycomb are shown in Table 2 in the Appendix. The values are based on aluminum type, density, and cell design. The strength values are similar from various manufacturers when these design parameters are the same.

The crush strength values are affected by dynamic loading as reported by (Hong, et. al.), with higher velocities creating higher forces.

The analysis given here is a starting point for design, and does not account for dynamic rate of the honeycomb or the dynamic rate change of the steel sub-structure.

Using aluminum honeycomb with a density of 80 kg/m^3 (5 #/f^{3}) and a crush strength of 17.3 kgf/cm^2 (245 psi), the following area can be calculated.

<u>Area of Absorber</u>

A = F/ kgf/cm^2 Where:
A is area of honeycomb cm^2
F is design limit force N
kgf/cm^2 is crush strength

A = (186,800/9.8)/17.3 = <u>1102 cm^2</u> (171 in^2)

Other densities of aluminum honeycomb shown in table 2 in the Appendix can be substituted, but the areas must be recalculated for the crush strength of that density honeycomb.

<u>Energy Absorbed Sample Calculation:</u>

The energy absorbed by the device is force multiplied by distance. The stroke of the honeycomb is the distance for which a constant crush strength force occurs. The constant force distance for this honeycomb is approximately 85% of the original thickness. So for example, a 127mm (5 inch) thick honeycomb will absorb energy at the crush strength for 108mm (4.25 inches).

Energy = **F** x **d** =186.8kN x 0.108m = <u>20,168</u> Joules (14,875 ft#)

Where: **F** is the force applied in kN
d is the distance in meters

The energy calculation can be converted to an equivalent impact velocity that can be absorbed for the mass of the vehicle. The mass of the vehicle is 1363.6 kg (3,000#).

The impact velocity absorbed can be calculated from:

$\mathbf{E_k} = ½\ m\ V^{2}$
$\mathbf{V} = (2 \cdot E_k/m)$^ ½ = 5.44 m/s = <u>19.6 KPH</u> (12.2 MPH)

Where: E_k = Kinetic Energy
m = Mass of Vehicle (kg)
V = Impact Velocity (m/s)

The impact velocity capability of the force limiting energy absorber can be calculated for varying thickness of honeycomb material. A plot of absorber thickness vs. impact velocity is shown Figure 4.

The limits to the energy capacity are directly proportional to the thickness of the absorber allowed by the packaging constraints of the race car design.

The aluminum honeycomb material deflects at the crush strength provided by the manufacturer. The crush is consistent if the impact angle is less than <u>+</u>15 degrees from parallel to the surface (Hong, et. al.).

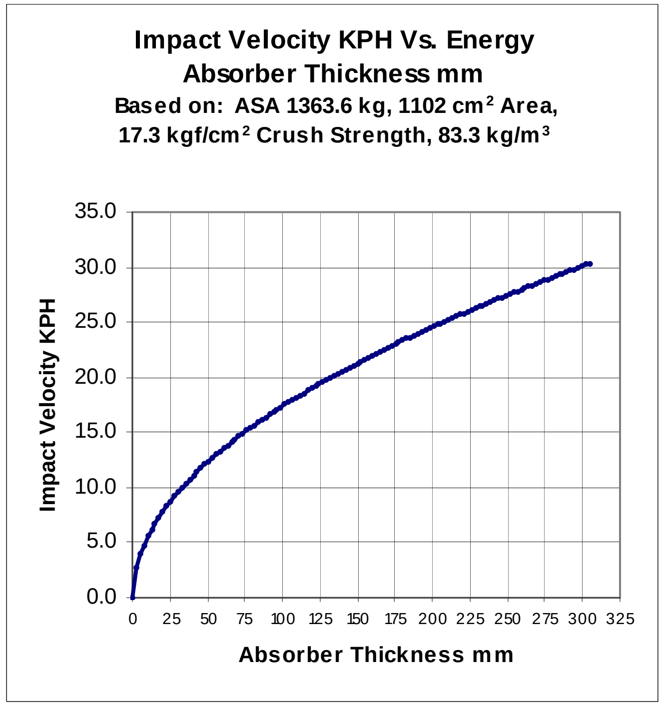

Figure 4

CONCLUSIONS

These preliminary strength tests of the ASA chassis showed:

1. The facility at Howe Racing has the capability of crushing a full size ASA race car chassis.
2. Force deflection of one side of a chassis can be performed without distorting the opposite side.
3. New center section designs can be compared as they are developed.
4. Calculations determining the size and strength of add on energy absorbers can be based on the strength measured from the existing chassis.

ACKNOWLEDGMENTS

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CONTACT

Thomas Gideon, GM Racing, 100 Renaissance Center, MC 482-A24-B36, Detroit, MI, 48265-1000, Telephone: (313) 667-1908, Fax: (313) 667-2939, Email: tom.gideon@gm.com

APPENDIX 1

Table 1 **Chassis Deflections (Millimeters)**

Press.	Force	A	B	C	D	E	F	G	H	I	K	L	Deflection
Bar	KN	LF POST	WIND-SHIELD	RF POST	TOP DOOR	BETWEEN POST	PLATE	CENTER REAR	RR POST	CR BOTTOM	LR POST	CL STROKE	mm
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.6	19.3	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	2.8	2.8
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
62.1	43.3	3.2	3.2	9.5	0.0	0.0	6.3	0.0	1.6	1.6	0.0	5.6	5.6
82.8	57.8	4.8	6.3	6.3	0.0	1.6	8.0	1.6	3.2	3.2	1.6	7.0	7.0
110.3	77.0	4.8	6.3	6.3	0.0	3.2	9.5	3.2	3.2	4.8	3.2	8.4	8.4
137.9	96.3	4.8	6.3	6.3	0.0	3.2	11.1	3.2	3.2	4.8	3.2	9.8	9.8
165.4	115.6	6.3	8.0	11.1	0.0	4.8	14.2	4.8	4.8	4.8	4.8	12.5	12.5
193.1	134.8	7.9	8.0	11.1	-1.6	6.4	19.1	4.8	4.8	6.3	6.3	16.8	16.8
220.6	154.1	9.5	9.5	12.7	-6.3	8.0	28.6	6.3	6.3	8.0	6.3	25.2	25.2
0.0	0.0	0.0	0.0	0.0	-6.3	3.2		0.0	0.0	0.0	0.0		0.0
248.2	173.3	9.5	11.1	12.7	-12.7	12.7	42.9	8.0	8.0	-11.1	8.0	37.7	37.7
275.8	192.6	9.5	11.1	12.7	-15.9	17.5	57.2	9.5	8.0	9.5	9.5	50.3	50.3
0.0	0.0	0.0	0.0	0.0	-15.9	12.7	36.5	0.0	0.0	0.0	0.0	32.2	32.2
303.3	211.8	12.7	12.7	14.3	-19.1	28.6	98.4	14.3	9.5	9.5	9.5	73.0	73.0
0.0	0.0	0.0	0.0	0.0	-19.1	27.0	73.0	0.0	0.0		0.0	64.3	64.3

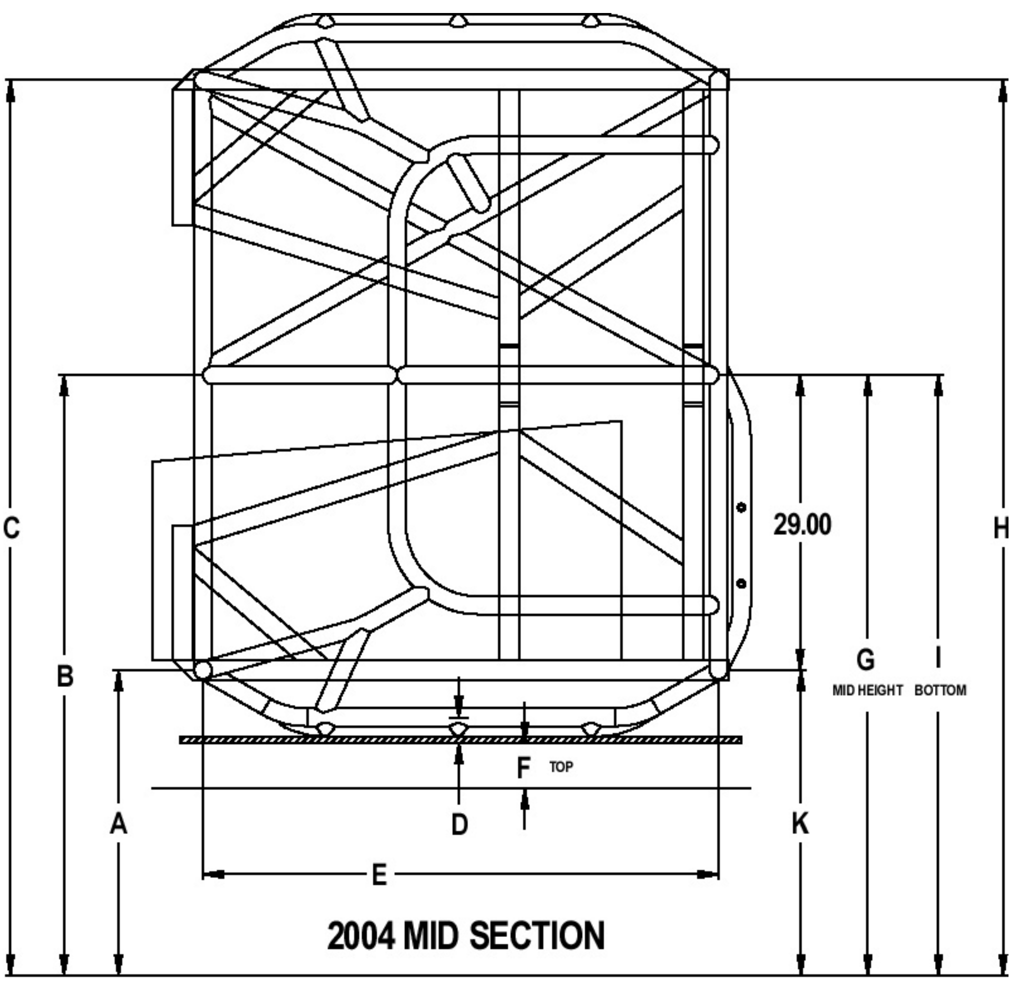

Figure 5

APPENDIX (continued)

Initial Pretest Condition

Displacement @ 192.6 kN

Figure 6

Figure 7

2004 Chassis Upgrades

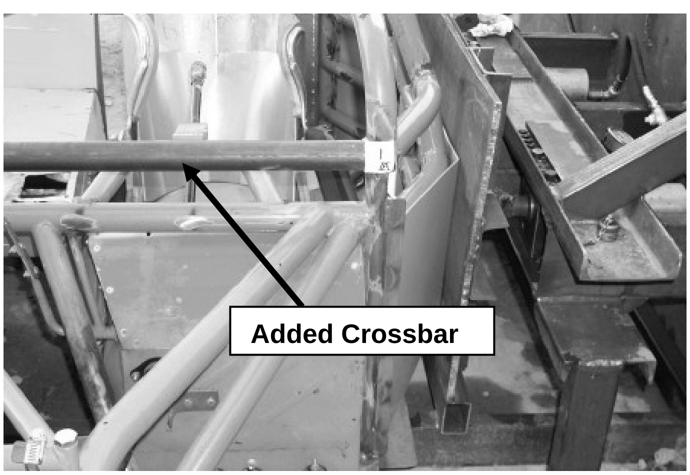

Figure 8

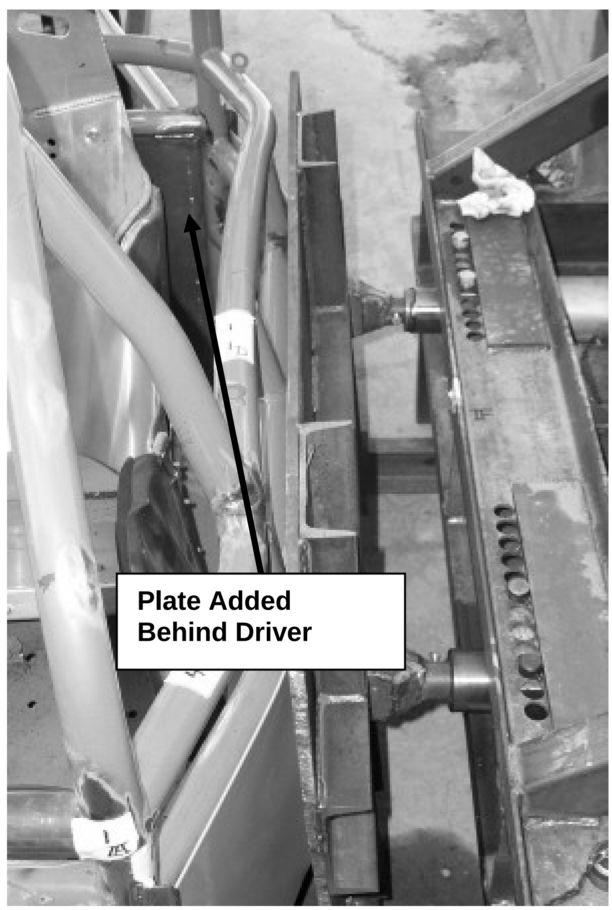

Figure 9

Appendix (continued)

Table 2

Plascore PCGA-XR1 3003 Commercial Grade Aluminum Honeycomb

Honeycomb Designation			Bare Compression	Crush Strength	
Cell Size	Foil Gauge	Density	Strength	Strength	Modulus
mm	mm	kg/m^3 (lbs/ft^3)	kgf/cm^2	kgf/cm^2 (psi)	Mpa
6.35	0.076	83.3 (5.2)	43.6	17.2 (245)	1020
9.52	0.076	57.7 (3.6)	22.8	8.4 (120)	634
12.70	0.076	40.0 (2.5)	11.6	4.2 (60)	276
19.05	0.076	28.8 (1.8)	7.7	3.2 (45)	165
25.40	0.076	19.2 (1.4)	5.3	1.8 (25)	110