humanIMPACTengineering

injury prevention through analysis, testing and design

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Re: Spinal Compression Testing
(Our Project Reference: P13-019)

Human Impact Engineering has completed testing of a number of seat base samples using a static seat base test method described by DeRosia et al. (2013), which is designed to demonstrate the loading effects of the seat structure on the human spine in frontal crashes. A "static seat testing (SST)" device measured the vertical force applied to a buttock form (based on an SAE J826 OSCAR H Point machine) as a seat base was pulled horizontally rearward. This is the analogue of a 50th%tile male dummy moving forward in a dynamic sled test.

This method was used to compare two current seat designs with a rigid anti-submarining seat pan structure to the modified seat structure fitted with the Lifebelt restraint system.

The SST peak vertical force developed by the unmodified front and rear seats was significantly greater than that from the modified seat structures with the Lifebelt restraint system.

Details of the testing and the results can be found in the attached report.

Please do not hesitate to contact us if you require further information.

Kind regards,

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Static Seat Testing Report

Test Apparatus

The "static seat testing (SST)" device, as described by DeRosia et al. (2013)[1], was used to test the resistance of various seat base samples to forward motion of an occupant during a forward collision.

The SST device consists of a buttock form (based on an SAE J826 OSCAR H Point machine) and a frame which restricts vertical movement of the buttock form as the seat base is pulled out horizontally from beneath. The apparatus is shown in Figure 1.

The SST incorporates a cart fastened to linear bearing riding on two parallel runners. The vehicle seat base sample, to be tested, is bolted to the cart with the seat tracks parallel to the cart plane of travel. The buttock form was mounted to a base plate which was hinged to a second plate along its front edge. Three uniaxial load cells were mounted to the upper plate. The other side of the load cells were mounted to two horizontal beams which were clamped in position. The vertical height of these beams could be varied, and then clamped for carrying out each test. An electric winch was used to pull the cart and seat base to the rear, out from beneath the rigidly mounted buttock form.

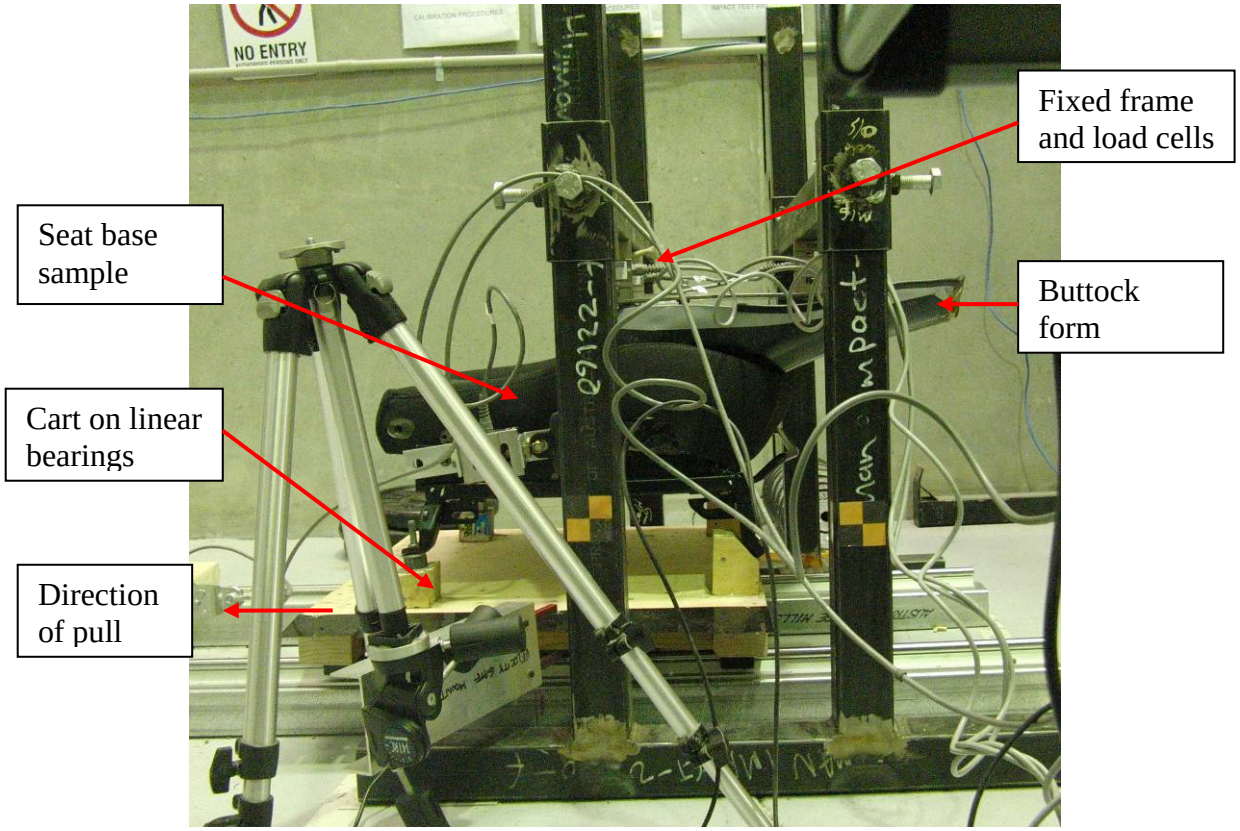

Figure 1 Static Seat Testing (SST) apparatus

Test Samples

The aim of the testing was to compare two current production anti-submarining seat pan structures, one front and one rear seat, to a modified seat structure fitted with the Lifebelt restraint system. The Lifebelt restraint system is a patented design which includes an extension of the existing seat belt webbing in a continuous loop around the upper thighs (i.e. within the seat structure and cushion). The device has undergone proof of concept

[1] DeRosia JJ, Pintar FA, Halloway DE, Meyer MA, Yoganandan N (2013) "Seat pan loading differences using a new test apparatus", Proceedings of the 23rd International Technical Conference on the Enhanced Safety of Vehicles (ESV), Seoul, Republic of Korea, May 27-30, 2013.

testing (Gibson et al., 2011[2]), demonstrating that it is an effective anti-submarining restraint system for both front and rear seat occupants. The device concept is pictured in Figure 2 below.

Figure 2 Lifebelt device concept

Two standard front seat bases from a current model vehicle were tested as a control, see Figure 3. The test seat bases were mounted with the seat rail horizontal. The structure of the seat base underlying the cushion is pictured in Figure 3.

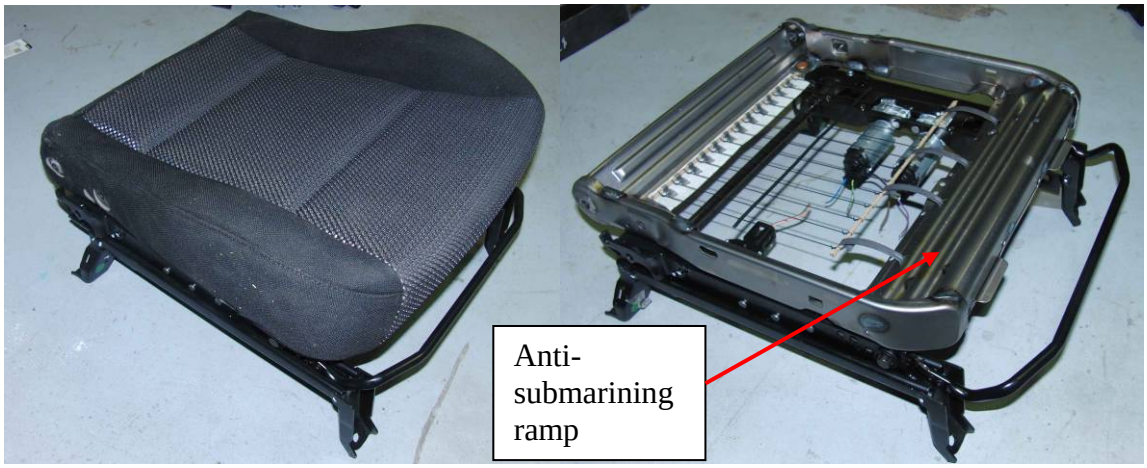

Figure 3 Standard front seat base.

Two front seat bases were fitted with the under lap portion of the Lifebelt restraint system and the seat sample was retested. In the first two of these tests (tests 3 and 4), shoulders were added to each side of the seat pan over which the under lap portion of the Lifebelt was placed. The rigid anti-submarining ramp was left unmodified. Following these tests, the seat base was modified with the front anti-submarining ramp structure cut away to avoid interference with the buttock form, see Figure 4. Extra strengthening was added to keep the integrity of the modified seat base. Two additional tests were performed with this set up (tests 5 and 6). The testing performed on the four front seat bases is summarised in Table 1.

[2] Gibson T, Clarke A, Pisaniello L, Stephan M, Fusco L, Judd R (2011) "Evaluation of an improved performance anti-submarining seat belt system", Proceedings of the 22nd International Technical Conference on the Enhanced Safety of Vehicles (ESV), Washington D.C., June 13-16, 2011.

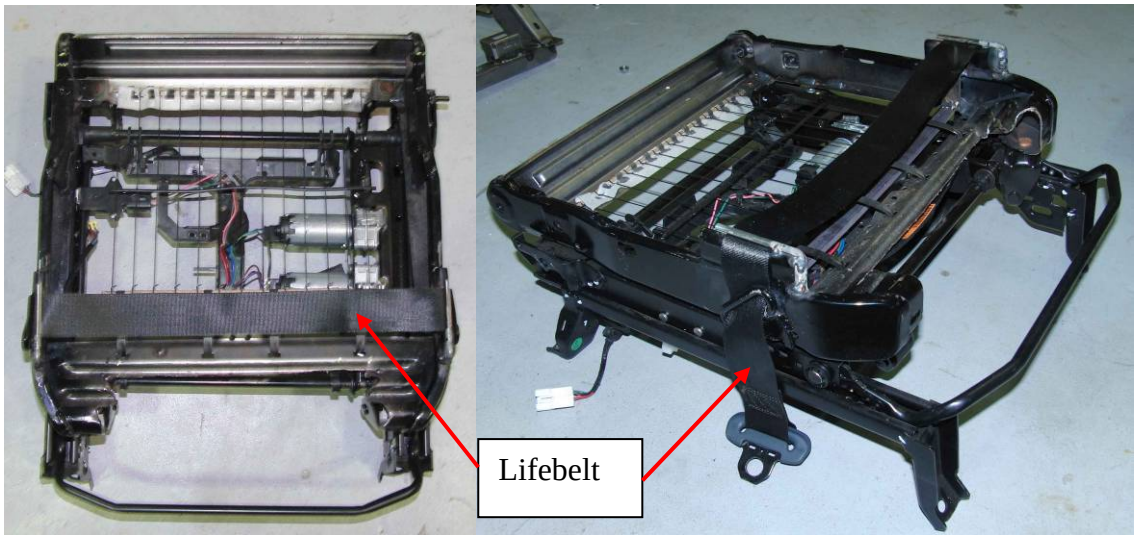

Figure 4 The front seat base structure with Lifebelt included.

Table 1 Testing of four front seat bases.

Test Number	Seat Model	Seat Modifications	Lifebelt	Initial Lifebelt Tension (N)
1	Front Seat	Unmodified	Not Fitted	n/a
2	Front Seat	Unmodified	Not Fitted	n/a
3	Front Seat	Unmodified	Fitted	0
4	Front Seat	Unmodified	Fitted	800
5	Front Seat	Modified and reinforced	Fitted	800
6	Front Seat	Modified and reinforced	Fitted	800

Two left hand sections of a current model vehicle rear passenger seat bases were tested. The standard seat base was tested first. The seat and the structure underlying the cushion are shown in Figure 5. The seat bases were both tested at the same angle used for the earlier sled test series.

Figure 5 The standard left passenger rear seat, showing the underlying structure.

The structure of one of the rear seat base sections was modified in a similar manner to the front seat base, Figure 6. The rigid structure at the front of the seat was removed and a under lap portion of a Lifebelt restraint system fitted. During the first two tests of the modified seat the angled bracket attachments deformed excessively. The seat structure was reinforced and two additional tests were performed. The testing performed on the rear passenger seat samples is summarised in Table 2.

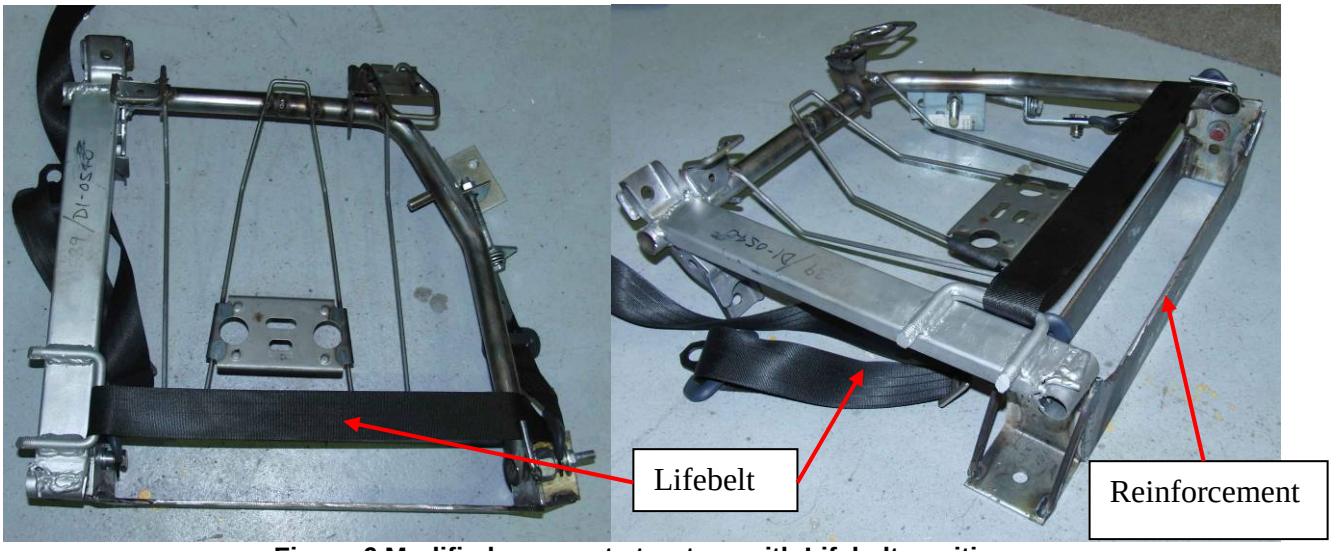

Figure 6 Modified rear seat structure with Lifebelt position

Table 2 Testing of rear seat base sections.

Test Number	Seat Model	Seat Modifications	Lifebelt	Initial Lifebelt Tension (N)
7	Left Rear Passenger Seat	Unmodified	Not Fitted	n/a
8	Left Rear Passenger Seat	Unmodified	Not Fitted	n/a
9	Left Rear Passenger Seat	Modified	Fitted	800
10	Left Rear Passenger Seat	Modified	Fitted	800
11	Left Rear Passenger Seat	Modified and reinforced	Fitted	800
12	Left Rear Passenger Seat	Modified and reinforced	Fitted	800

Test Methods

The test sample was fixed to the cart with the seat tracks parallel to the cart direction of travel. For the front seat tests, Tests 1 - 6, the seats were identically mounted to the cart with the seat slides horizontal. The same applied for the rear seat tests, Tests 7 - 12.

The buttock form was settled vertically into the test seat base and the position marked. Each test seat base was brought forward underneath the buttock form to this zero position. Additional weights were placed on top of the buttock form assembly so that the total weight resting on the seat was 930 N and the device was allowed to settle into position. The angle of the buttock form was stabilised at approximately 20 degrees with a level reference plane for the load cells. The horizontal beams were then clamped in position.

The seat was pulled slowly rearward by an electric winch, pausing every 50 mm of travel. The process continued until the seat was pulled free or the measuring range of the load cells was reached.

Test Results

Front Seat
The maximum seat pan and lifebelt load reached for the front seat testing is summarised in Table 3. Note that in some of the tests, the load on the buttock form was greater than was readable by the load cells and as a result the peak value could not be established. When this occurred, the value is presented in red in the table. The loads on the seat pan and the lifebelt for each test are shown in Figures 7 – 11.

Table 3 The maximum seat pan and Lifebelt load reached for the front seat testing.

Test Number	Seat Model	Seat Modifications	Lifebelt	Max Seat-pan Load (N)	Max Lifebelt Load (N)
1	Front Seat	Unmodified	Not Fitted	9500+	n/a
2	Front Seat	Unmodified	Not Fitted	9500+	n/a
3	Front Seat	Unmodified	Fitted	9500+	1976
4	Front Seat	Unmodified	Fitted	9500+	2752
5	Front Seat	Modified and reinforced	Fitted	5613	2184
6	Front Seat	Modified and reinforced	Fitted	6355	2418

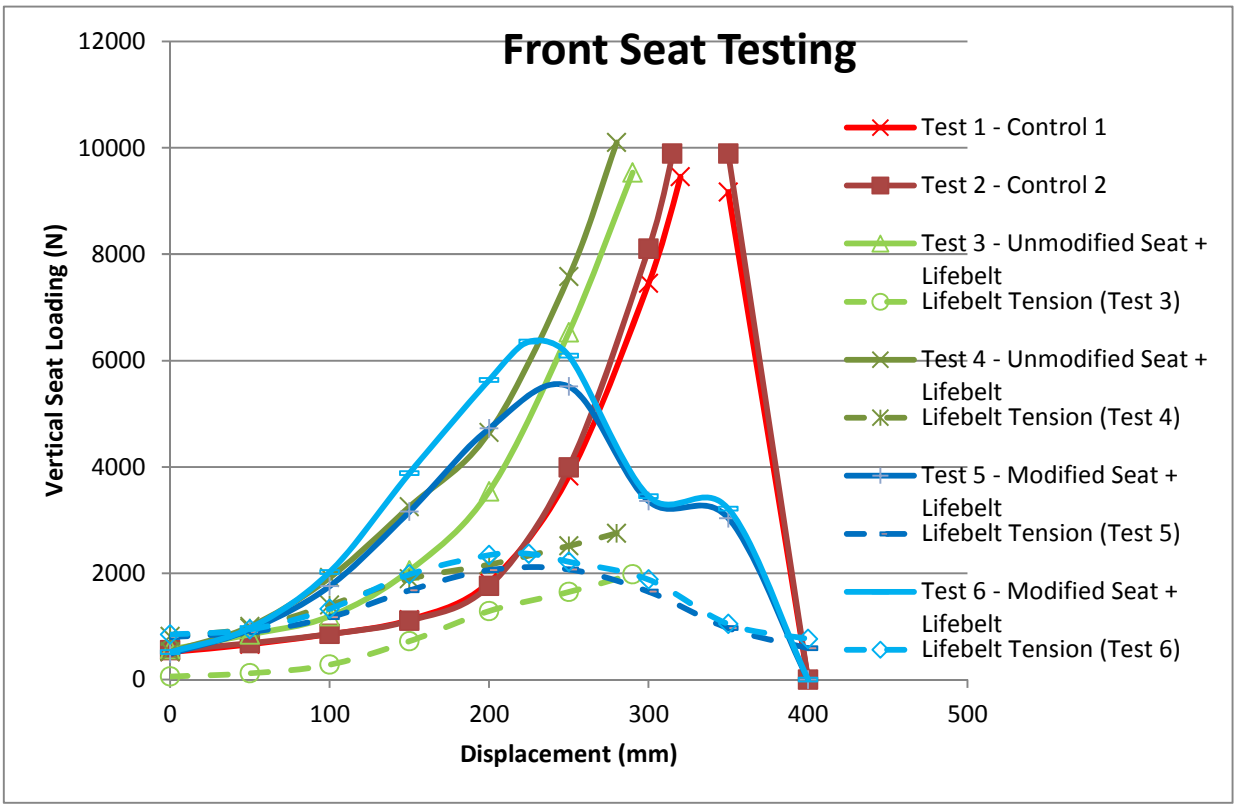

Figure 7 Load v Displacement summary of the front seat tests.

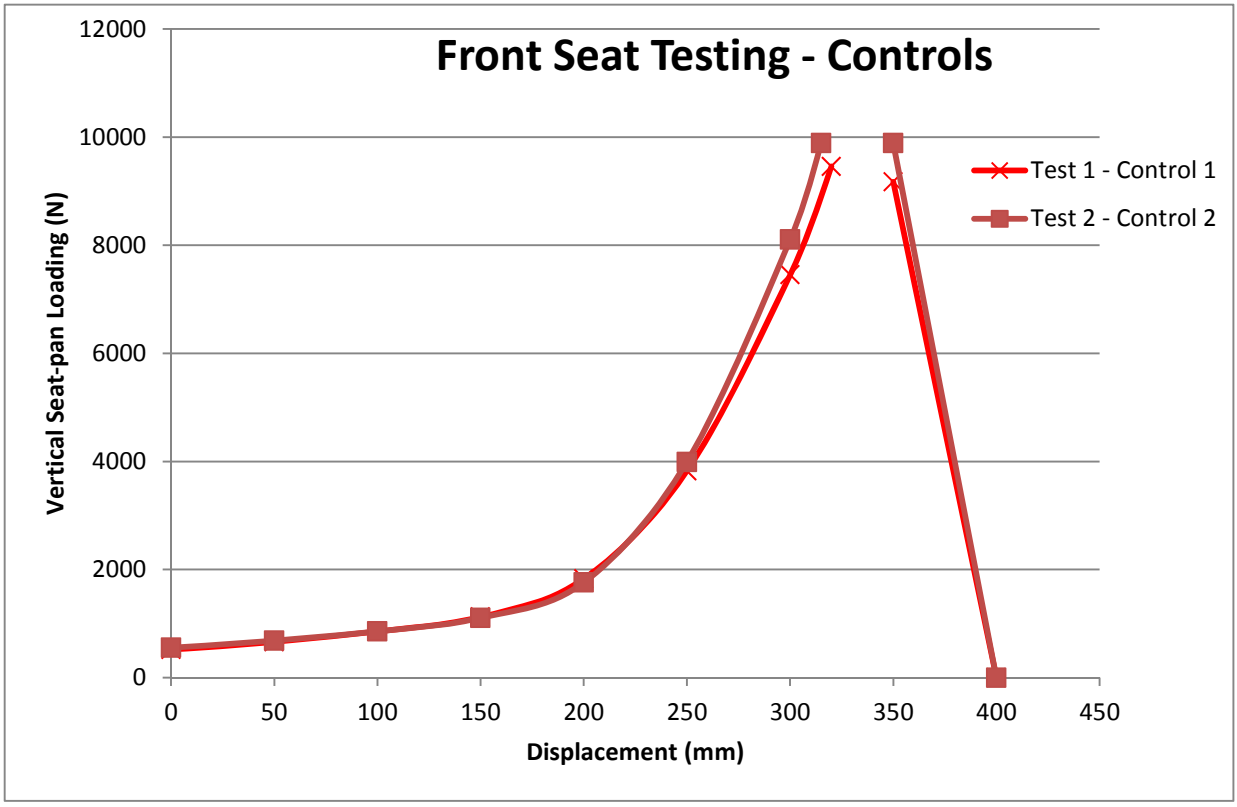

Figure 8 Load v displacement for the standard unmodified front seat.

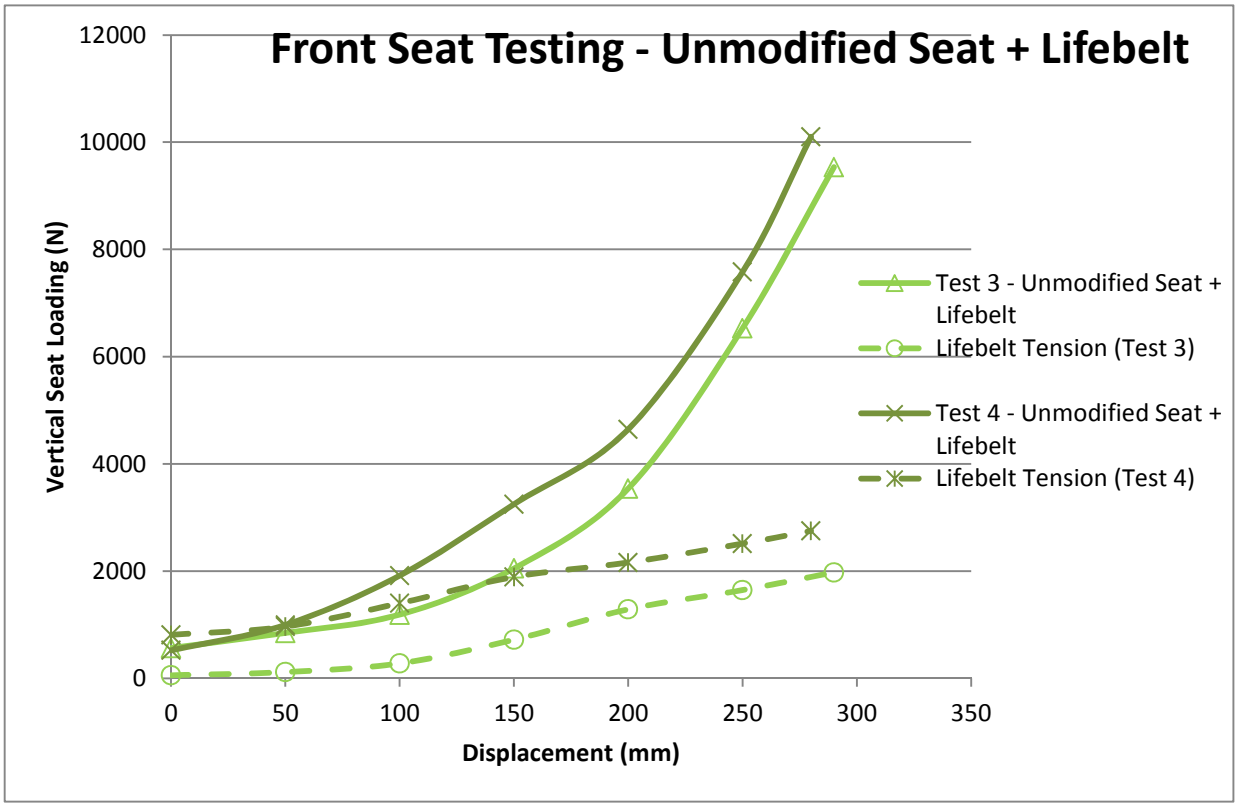

Figure 9 Load v displacement for the unmodified front seat fitted with the Lifebelt restraint. Note that the Lifebelt was not tensioned in Test 3. In Test 4, an initial tension of 800 N was applied to the Lifebelt.

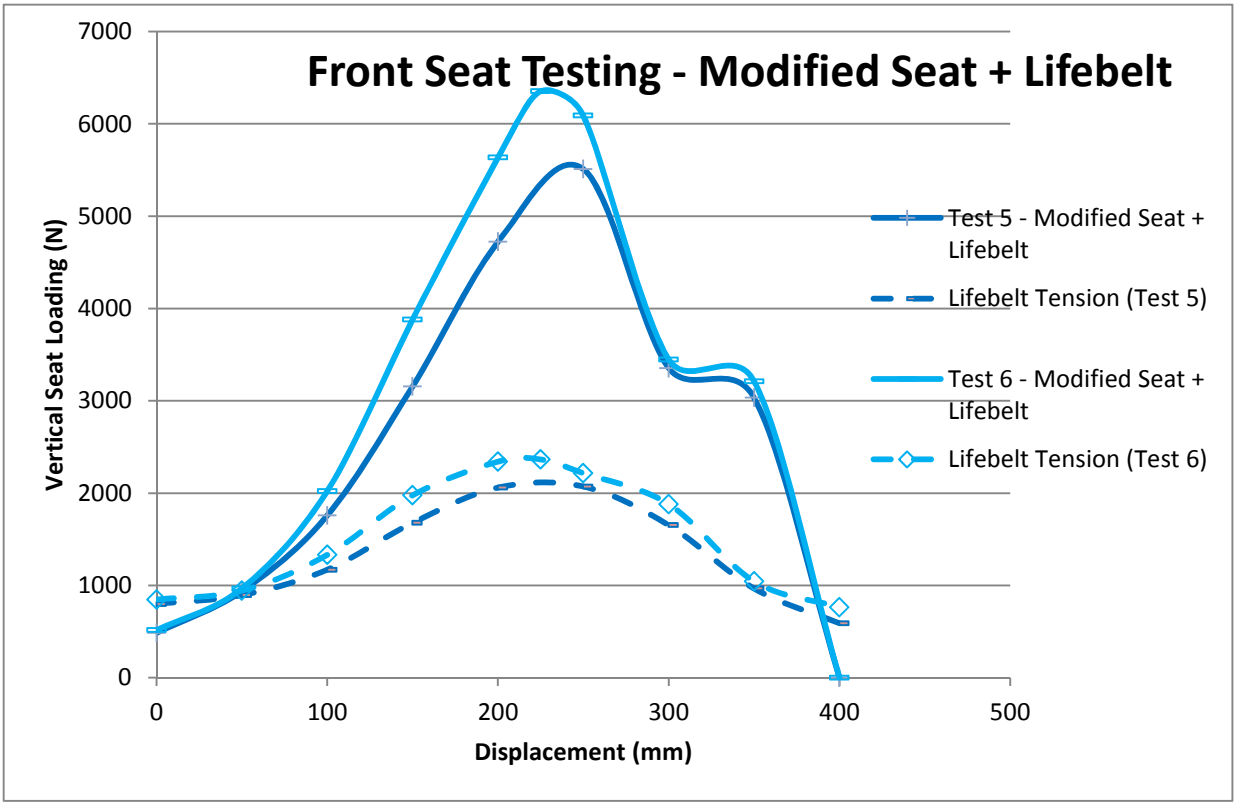

Figure 10 Load v displacement for the modified front seat fitted with the Lifebelt restraint. Note that in Tests 5 and 6, an initial tension of 800 N was applied to the Lifebelt.

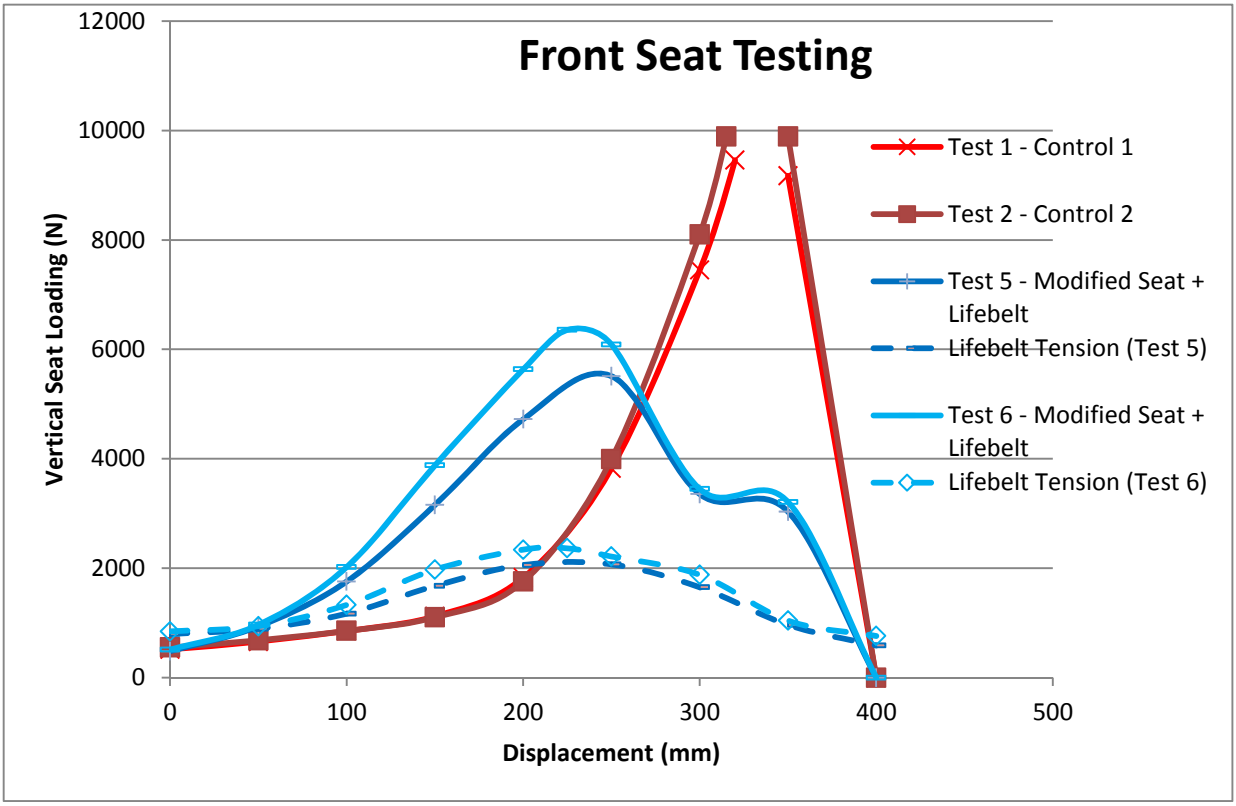

Figure 11 Load v displacement comparison between the standard unmodified front seat and the modified front seat fitted with the Lifebelt restraint.

Rear Seat

The maximum seat-pan and lifebelt loads reached in the rear passenger seat testing is summarised in Table 4. In Test 7, the left rear seat mount failed causing the seat to deform. The testing was stopped following the seat mount failure. The load reached the maximum limit of the load cells in Test 8, indicated by the red text. In Tests 9 and 10, the force data measured on the seat pan was noisy with numerous sharp peaks. After the testing, severe inward deformation was noted on each side of the seat at the Lifebelt attachments. The seat was reinforced and tested twice more. No deformation was noted in Tests 11 and 12. The loads on the seat pan and the lifebelt for each test are shown in Figures 12 – 16.

Table 4 The maximum seat pan and Lifebelt load reached for the rear seat testing.

Test Number	Seat Model	Seat Modifications	Lifebelt	Max Seat-pan Load (N)	Max Lifebelt Load (N)
7	Left Rear Passenger Seat	Unmodified	Not Fitted	8126	n/a
8	Left Rear Passenger Seat	Unmodified	Not Fitted	9000+	n/a
9	Left Rear Passenger Seat	Modified	Fitted	5329	928
10	Left Rear Passenger Seat	Modified	Fitted	4646	981
11	Left Rear Passenger Seat	Modified and reinforced	Fitted	3381	1666
12	Left Rear Passenger Seat	Modified and reinforced	Fitted	3920	1815

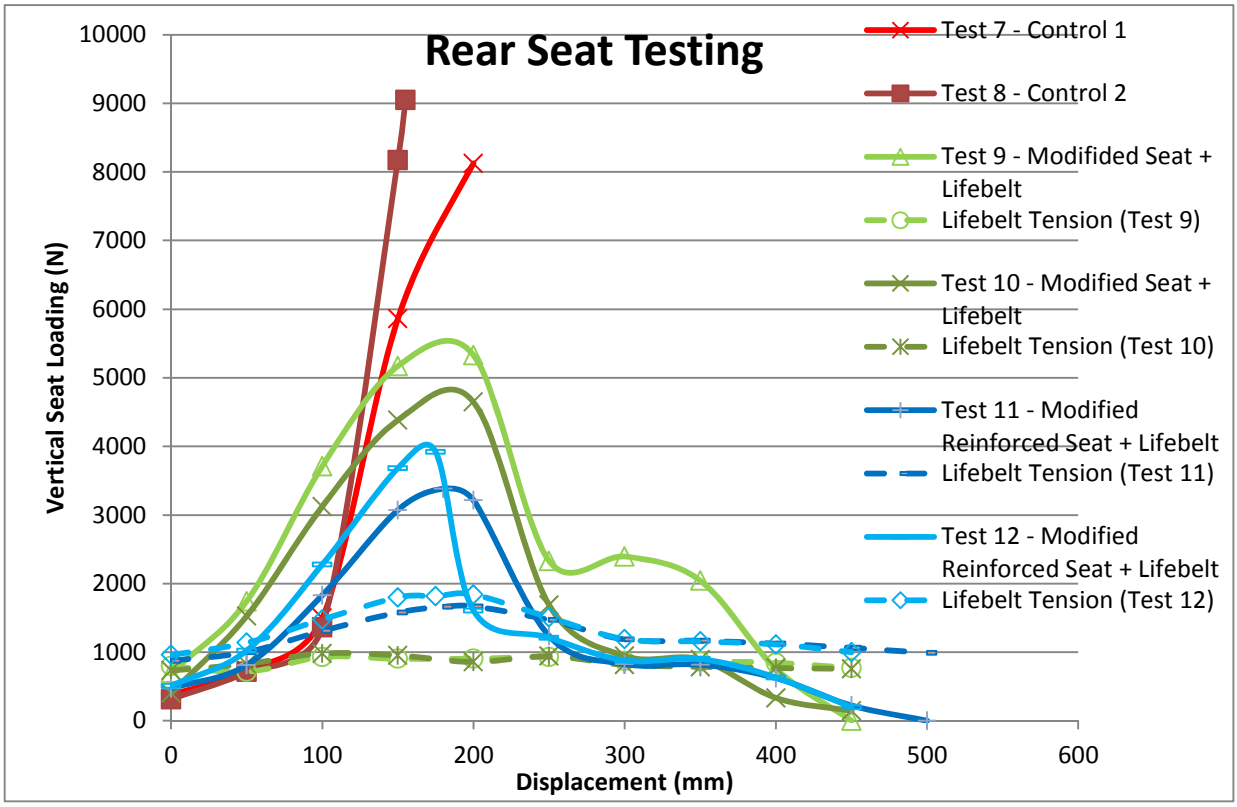

Figure 12 Load v Displacement summary of the rear seat tests.

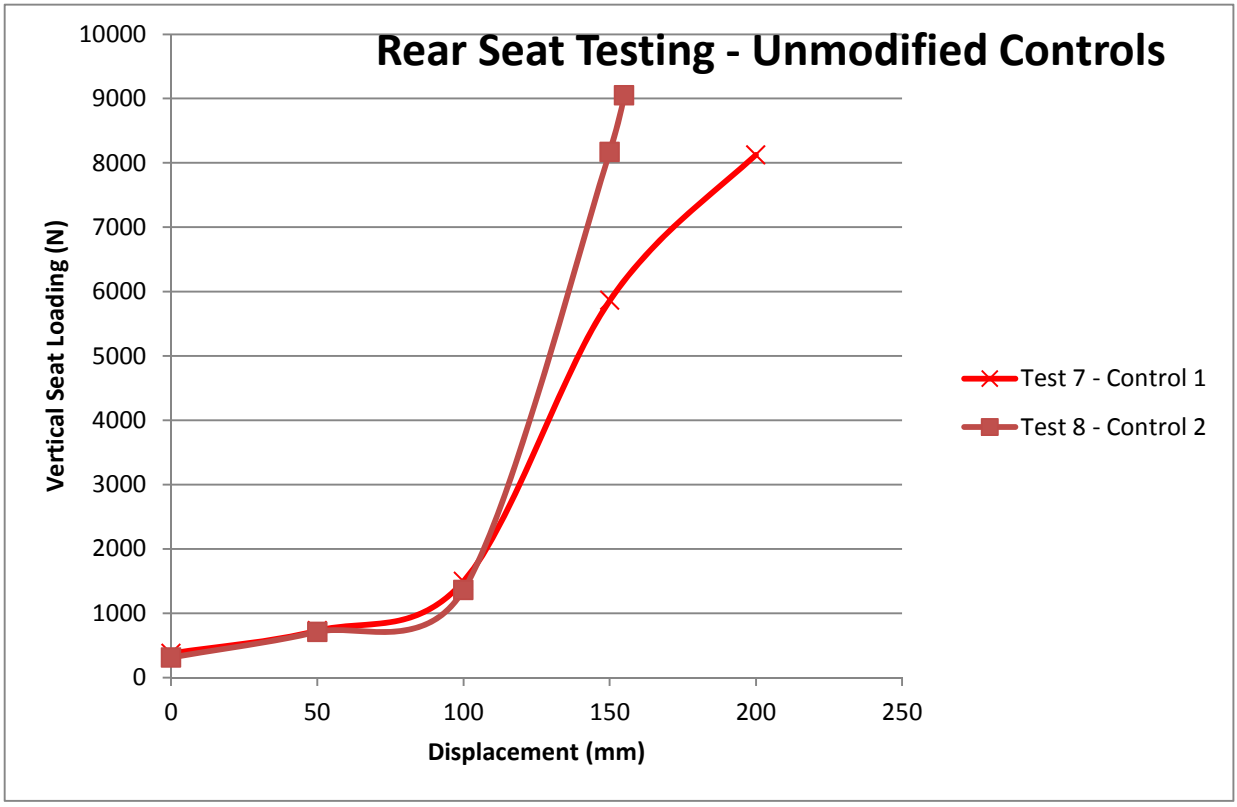

Figure 13 Load v displacement for the standard sectioned rear passenger seat. Note that in Test 7, the rear left seat mount failed causing the seat to be depressed during the test. Testing was stopped at this point.

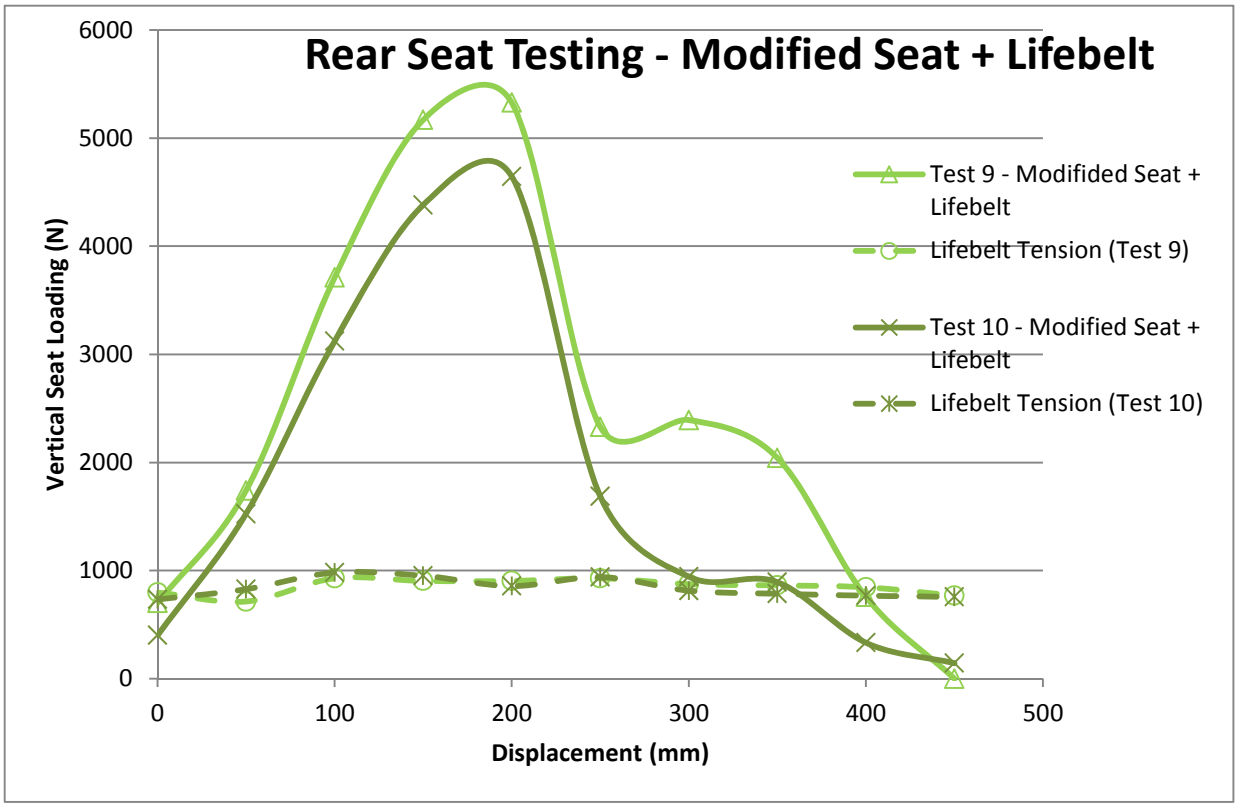

Figure 14 Load v displacement for the modified rear passenger seat fitted with the Lifebelt restraint. Note that in Tests 9 and 10 there was inward deformation of the angle brackets anchoring the Lifebelt.

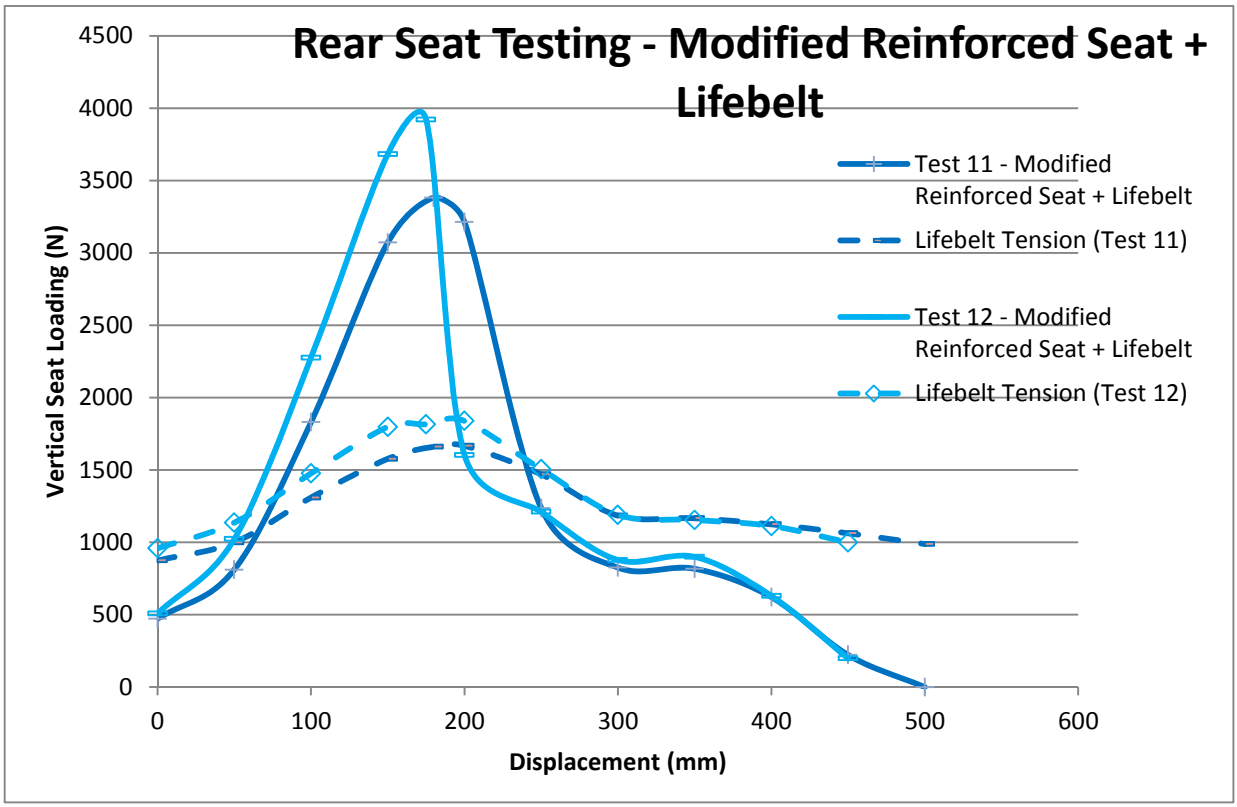

Figure 15 Load v displacement for the modified and reinforced rear passenger seat fitted with the Lifebelt restraint.

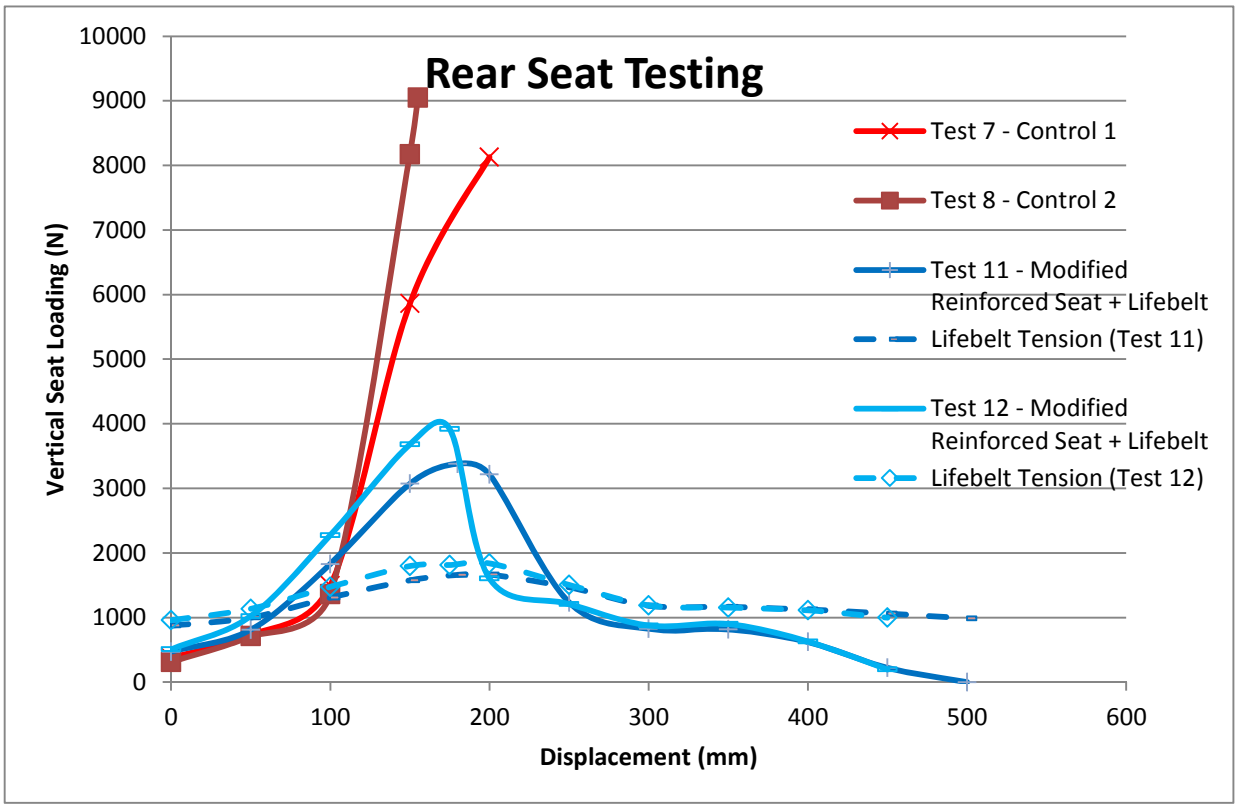

Figure 16 Load v displacement comparison between the standard rear passenger seat and the modified and reinforced rear seat fitted with the Lifebelt restraint.