Development of a Methodology for Substantiation of Replacement Seat Cushions - Phase I

Presented to: Seventh Triennial International Fire & Cabin Safety Research Conference

By: Richard DeWeese

Date: 4 December 2013

Talk Overview

- **Background**
- **Test Procedure Development**
- **Seat Frame Effects (Phase I)**
- **Conclusions**
- **Future Work (Phase II)**

Background

- Current aircraft seat bottom cushion replacement policy (ANM-115-05-005) for Transport Category seats is only applicable to cushions made from a single foam type. It utilizes a component test which evaluates only the foam.
- Most Transport Category cushions combine multiple foam types, have complex shapes, and are covered with a variety of materials. A test method that can evaluate the performance of typical replacement cushions would help operators ensure that the original level of safety provided by the seat system is maintained when crucial safety components are replaced.

Background

- **Since rigid seat tests results were used to validate the component test method utilized in the current policy, it was postulated that a rigid seat test could also be used to directly compare entire cushion assemblies.**
- **A replacement methodology utilizing rigid seats would need to:**
  - Be repeatable and reproducible
  - Be validated to ensure that cushion test results produce the same trends as when the same cushions are tested in real seats

Test Procedure Development

- **Goals**
  - Maximize repeatability and reproducibility
    - Identify variables that affect results
    - Develop methods to control variables
    - Quantify expected range of results
  - Ensure meaningful results are produced
    - Determine sufficient test article configuration
    - Determine test seat features to emulate

Maximize Repeatability and Reproducibility

- **Variables affecting results**
  - **Occupant initial position**
    - Seating the ATD 1 inch higher than nominal increased lumbar load by 344 lb. (tests with same ATD and cushion construction)

Number of Tests	H-Point Z Height	Avg Lumbar Load (lb)
3	Nominal 1g	1,221
3	Nominal 1g + 1 inch	1,565

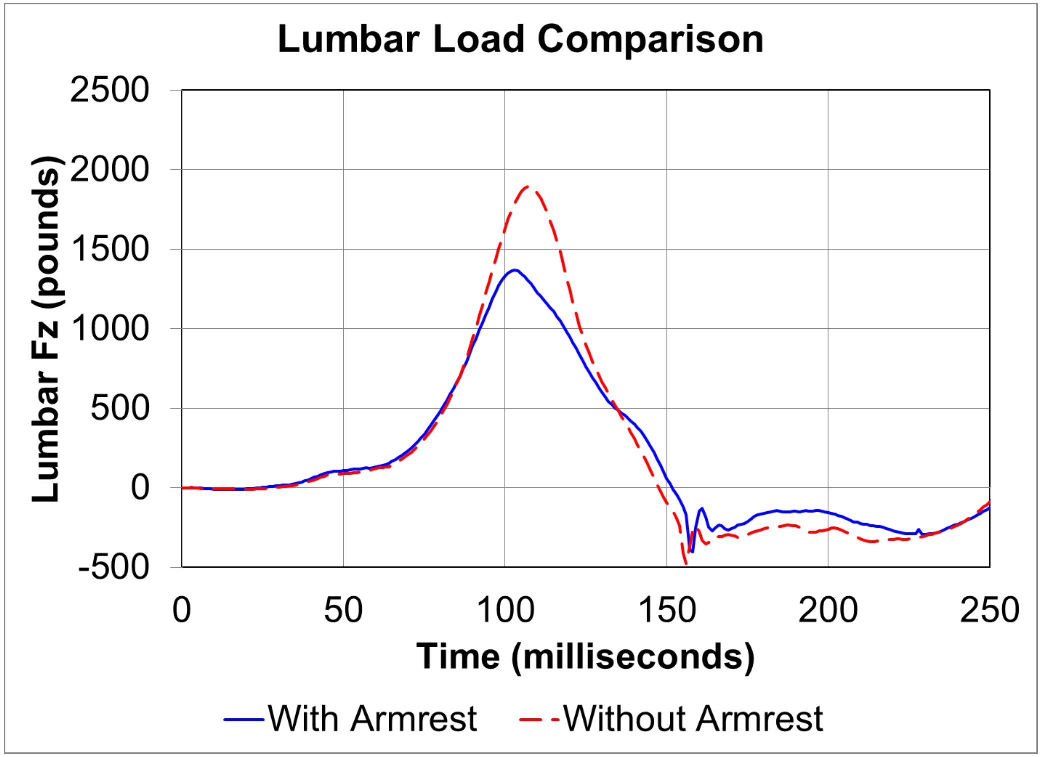
Maximize Repeatability and Reproducibility

- **Variables affecting results (cont)**
  - **ATD differences in pelvis construction / wear**
    - A difference in 0.5 inches in the compressed thickness of rubber skin/foam on the bottom of the pelvis contributed to significant differences in lumbar load. (the H-point Z height of ATD 1 is ~0.5 inches taller than ATD 2 when measured relative to a flat seat pan)

Cushion	ATD 1 (lb)	ATD 2 (lb)	Delta (lb)
A	1,985	1,833	163
B	1,772	1,355	417
C	2,007	1,623	384
D	1,825	1,588	237

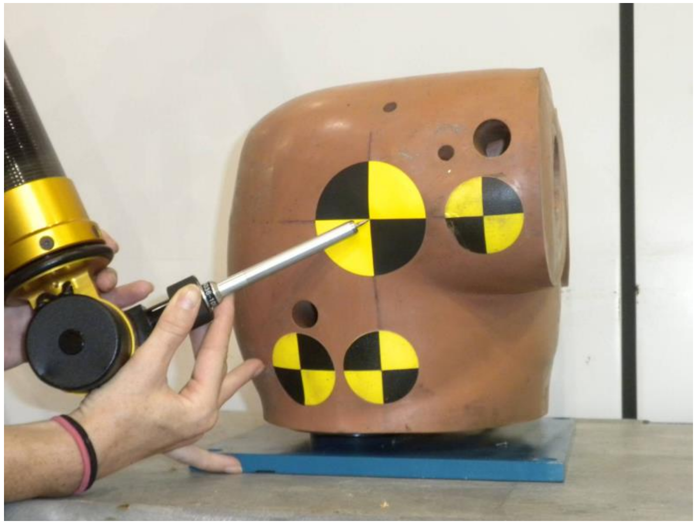
Maximize Repeatability and Reproducibility

- **Variables affecting results (cont)**
  - **ATD arm interaction**
    - ATD arms resting on seat armrests can become a secondary load path, reducing the lumbar load.



Maximize Repeatability and Reproducibility

- **Develop methods to control variables**
  - **Pelvis marking** facilitates accurate initial positioning.
  - **Initial Position tolerances** were used to ensure consistency during research tests.
    - ± 1° pelvis angle
    - ± 0.1” for the H-Point (x, z)
    - ± 2° torso angle (H-Point to Head CG)
    - ± 0.2” for the head CG (x)

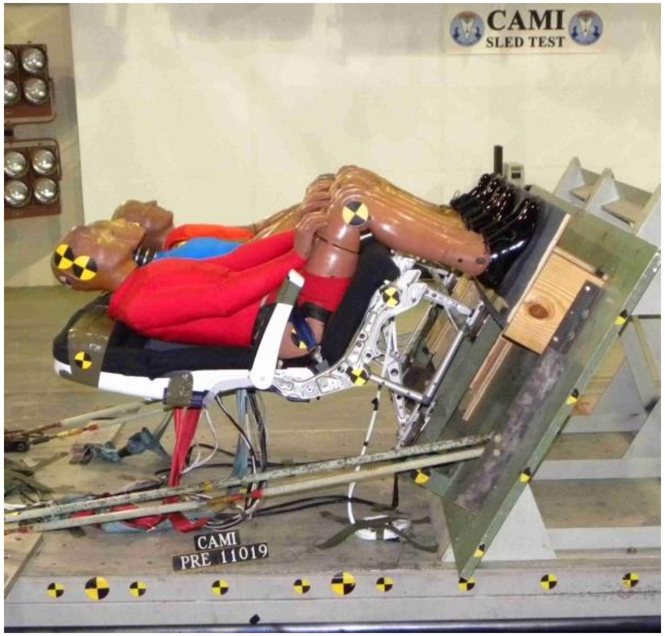


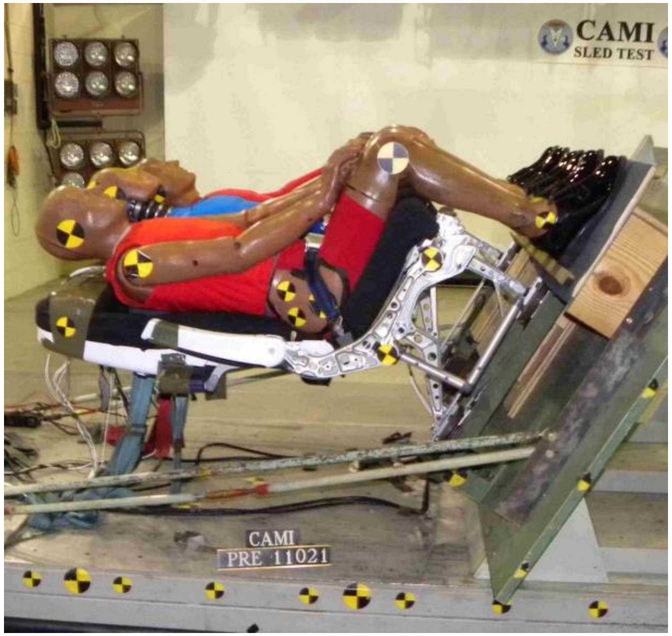
Maximize Repeatability and Reproducibility

- **Develop methods to control variables (cont)**
  - **Use of same ATD** for determining nominal 1-G preload position and for dynamic comparison tests
    - Hybrid II pelvis specifications do not control the thickness of rubber and foam on the bottom of the pelvis. There is currently no vertical calibration requirement for this ATD. The only practical solution at this point is to use the same ATD (and pelvis) for all lumbar load comparison tests.
    - The Hybrid III pelvis specifications control the thickness of rubber and foam under the pelvis with a compressed height test. The close tolerance required (± 0.06 inches) should improve the reproducibility of the lumbar load in tests with the FAA Hybrid III that uses this pelvis.

Maximize Repeatability and Reproducibility

- **Develop methods to control variables (cont)**
  - **Armrest removal or folding** (if feasible)
  - **ATD arm initial position** selected to minimize contact with armrests.

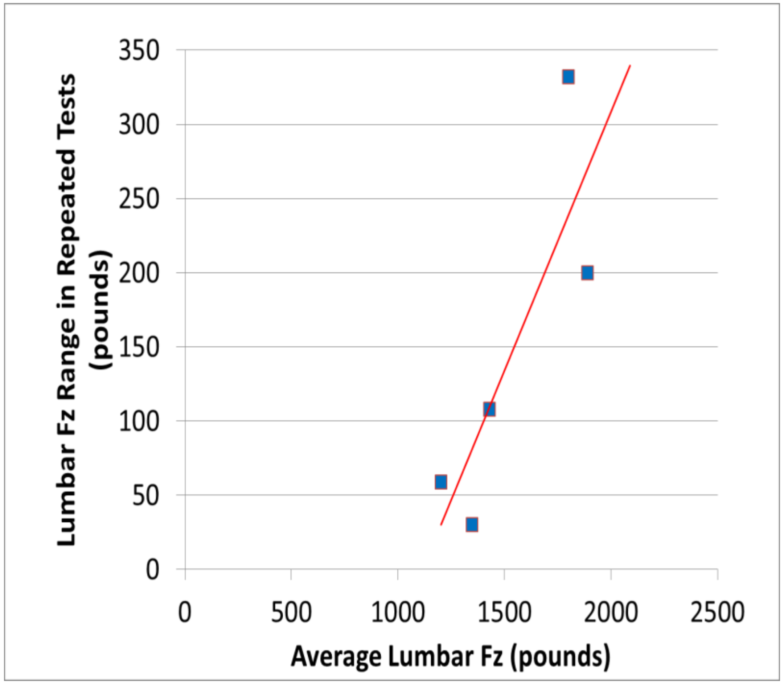




Maximize Repeatability and Reproducibility

- **The range of results is still significant even when variables are well controlled. The range may be related to load magnitude.**

Cushion	Thickness (in)	# of Tests	Low (lb)	High (lb)	Range (lb)
DAX 90	4.6	2	981	1,042	61
DAX 47	4.5	3	1,333	1,363	30
DAX 47 w/ leather cover	4.5	3	1,178	1,237	59
Airflex 40-50	4.5	3	1,796	1,996	200
Airflex 40-50	3.5	4	1,604	1,936	332
Airflex 40-50	2.0	3	1,385	1,493	108



Ensure Meaningful Results are Produced

- **Test article should consist of entire cushion assembly.**
  - Cover can affect stiffness since it acts as a barrier to airflow out of the cushion as it is compressed. Air flow is one reason that cushion static F/D characteristics differ from dynamic F/D.
  - Contoured cushions often have varying material type and thickness over the span and breath of the cushion. Testing the entire cushion permits direct evaluation of the affect of the cushion shape.

Cushion	Number of Tests	Avg Lumbar Load (lb)
DAX 47 No Cover	3	1,347
DAX 47 Leather Cover	3	1,202

Ensure Meaningful Results are Produced

- **Test seat must emulate those features that affect cushion vertical response.**
  - Initial shape of real seat pan when loaded at 1 G to include the deflected shape of cloth seat pans and pan features that could cause force concentration. The rigid shape should not deflect significantly during the test.
  - Seatback positioned to provide correct fore/aft pelvis position. Important since bottom cushion thickness can vary in the fore/aft direction.
  - A rigid, un-upholstered back at a nominal 103 degree angle (from horizontal) is conservative since all of the occupant’s vertical inertial load would be supported by the bottom seat cushion and feet.

Ensure Meaningful Results are Produced

- **Test seat emulating those features that affect cushion vertical response. (cont.)**
  – A rigid floor or rudder pedals at the representative position ensures the correct distribution of occupant inertial load between the seat pan and the floor or pedals.
  – Restraint system and anchorage points are placed at the same position relative to the cushion. Since the combined vertical/horizontal test has a significant horizontal component, the anchor location may affect pelvis rotation and horizontal translation.

Phase 1 - Seat Frame Effect

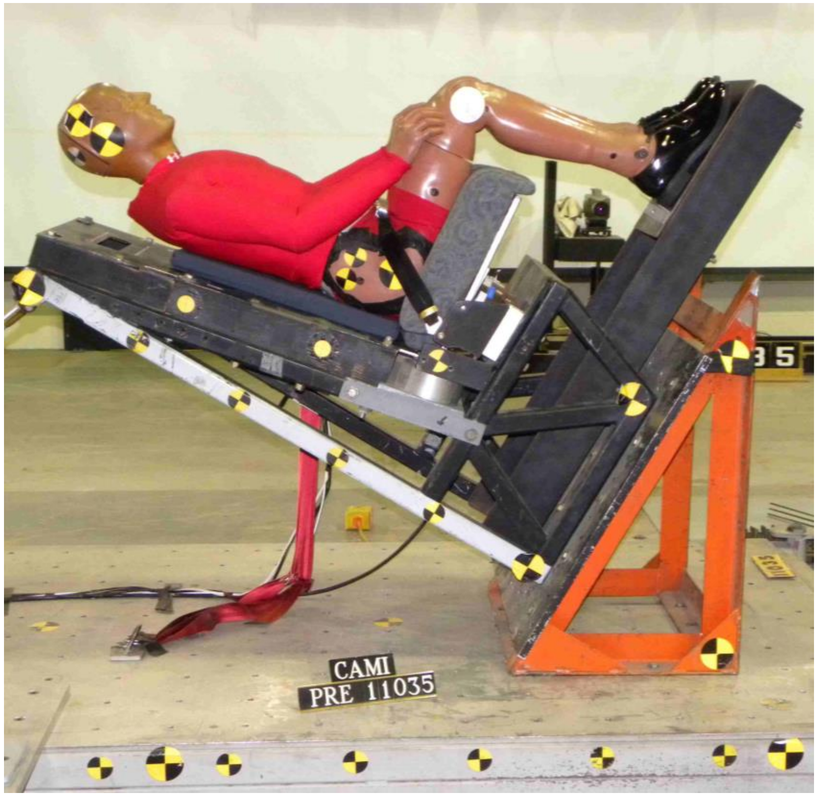
- **Goal**
  - Compare response of a seat place having nearly rigid support with one that is cantilevered. In previous research and certification tests, cantilevered seat places have produced lower lumbar loads than well-supported ones.
  - Compare real seat response to rigid seat response.

Phase 1 – Test Methods

- **Real seat configurations**
  - Triple place with seat leg under each outboard place
  - Triple place with seat legs near sides of center seat
  - The real seats had a flat 0.03 inch thick, perforated aluminum seat pan spanning the front and rear lateral support tubes at a 3 degree up angle. Pan attached to tubes with rivets along top of tubes.

Phase 1 – Test Methods

- **Rigid seat configuration**
  - Rigidly supported seat pan size and shape of real seat pan. (5 degree up angle)
  - Belt anchors and floor located in same position relative to cushion as on real seat.
  - Shim placed behind ATD to place pelvis in same fore/aft position with respect to cushion as on real seat.



Phase 1 – Test Methods

- **Seat cushion**
  - Same prototype seat cushion was used for all tests.
  - Exact material unknown but the loaded area consisted of a 0.5 inch top layer of very soft, open cell foam, 2.75 inches of medium density open cell foam, and 0.5 inch of dense, closed cell (flotation) foam. The flotation foam layer was cored out 3 inches diameter in the two areas directly under the occupant’s pelvic bone (ischial tuberosities). This would tend to soften the cushion in this area.
  - The cushions were covered in a tight-fitting, fire-blocking material and used a removable cloth dress cover.
  - The cushions attached to the seat pan with hook and loop strips.

Phase 1 – Test Methods

- **ATD**
  - The same Hybrid-II ATD was used for all tests. A new pelvis and lumbar spine was installed at beginning of test series.
- **Test severity**
  - Goal was the combined vertical/horizontal test cited in 25.562 (60-degree orientation to the loading direction, 14 G, 35 ft/s).
- **Data Processing**
  - Electronic and photometric data gathered per SAE J211.
  - Lumbar peak values normalized to the 14 G peak goal for comparison.
  - Position of pelvis tracked using photometric analysis.

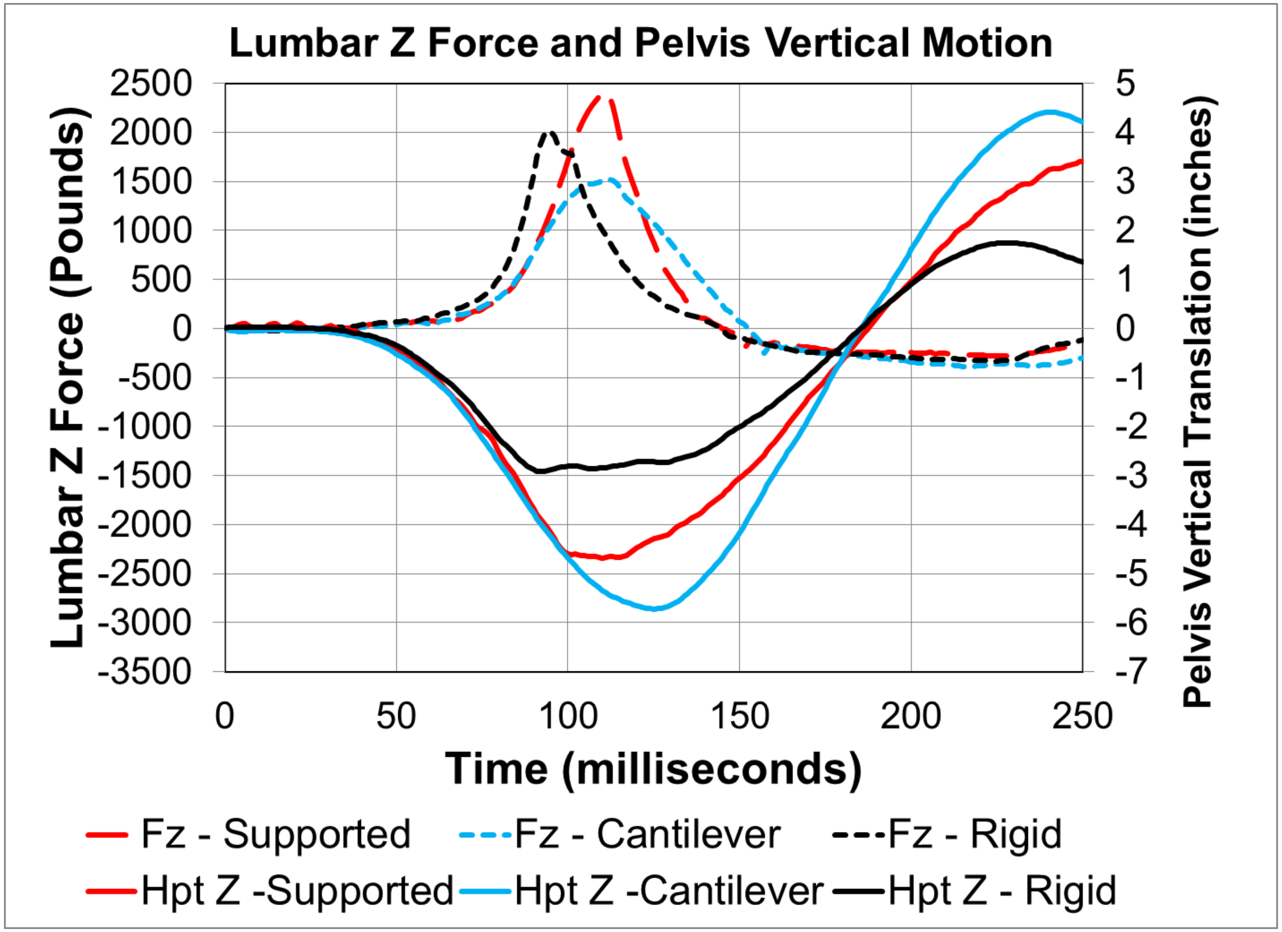
Phase 1 – Test Results

- **Well supported seat place:**
  - Seat pan was initially flat and deformed permanently 0.1 inch. There was negligible permanent deformation of the support tubes.
- **Cantilevered seat place:**
  - Seat pan deformed 0.1 inch. The ends of the support tubes were displaced downward 0.85 inch (indicating energy absorption).

Test #	Seat Config	Sled Peak G	Pelvis Peak Fz (lb)	Pelvis Fz Normalized (lb)
A11013	Supported	14.9	2,408	2,263
A11014	Cantilevered	14.5	1,536	1,483
A11035	Rigid	15.0	2,025	1,896

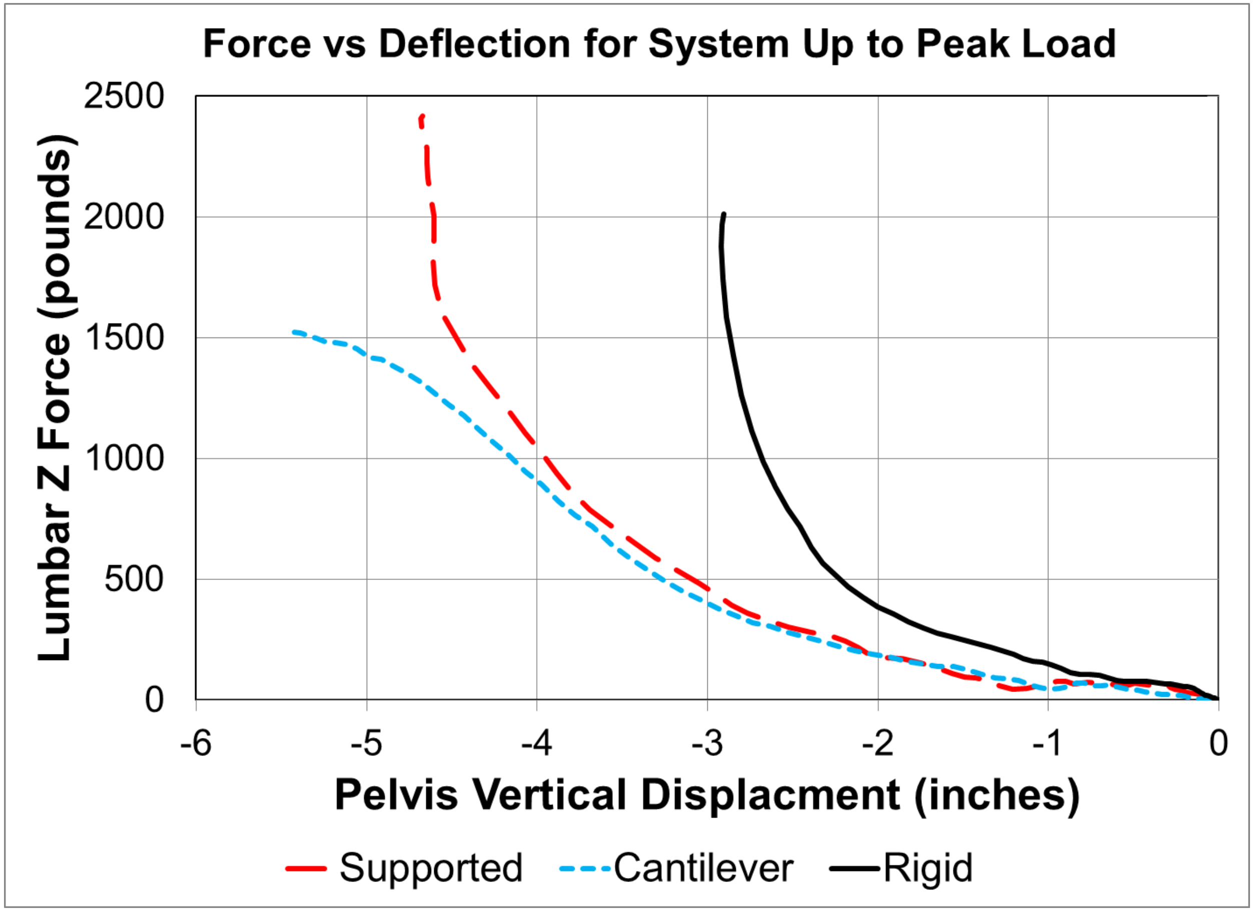
Phase 1 - Test Results

- Magnitude of displacement does not always correspond to magnitude of lumbar peak force.
- Phasing of motion and load apparently correspond. Vertical motion stops at or before the peak load for the two highest loaded seats.



Phase 1 - Test Results

- Plotting lumbar force vs. pelvis displacement shows that for both the supported and rigid seats, the system “bottomed out,” driving the load up.
- In this case, the supported seat with a stiffness falling between the others produced the highest load.



Phase 1 – Discussion of Results

- **Overall Stiffness Effect**
  – A rigidly supported cushion is not always the "worst case" for lumbar Fz. The results in this case, where the seat with an intermediate overall stiffness produces the highest lumbar load, are in agreement with the "criterion curve" behavior first noted by Hooper (Ref AR-05/5-1). He noted that as cushion stiffness progressed from soft to firm, there existed a intermediate stiffness that would produce the highest lumbar load. The results from this study indicate that the concept may also apply to the vertical response of entire seat system, not only the cushion.

Phase 1 - Discussion of Results

- **Cantilever Seat Place Performance**
  - The nearly linear force-deflection characteristic of the cantilevered seat place dominated that seat’s response, lowering the lumbar load in comparison with the well supported or rigid seats, in which the non-linear (progressively stiffer) characteristic of the cushion dominated, bottoming out before the energy was dissipated.

Conclusions

- **A test method has been developed for dynamic evaluation of seat cushions.**
  - Method minimizes test variability.
  - Suitable for evaluation of cushion assemblies regardless of shape or construction.
  - Emulates the seat features that could affect lumbar Fz produced.
- **Lumbar Fz produced during dynamic tests of a real seat is related to overall force / deflection of the system.**
- **The nearly linear bending response of seat lateral support tubes tend to lower lumbar loads for cantilevered seat places vs. well supported ones.**

Future Work (Phase II)

- **Evaluation of cushion performance when installed on a flexible (cloth) seat pan at both supported and cantilevered seat places. The test cushions will be made from a variety of foam types currently used for aircraft seats.**
- **Results to be compared with rigid seat tests to determine if the rigid seat results are predictive of the real seat results.**

Acknowledgments

- **Co-Authors:**
  - David Moorcroft
  - Amanda Taylor
- **CAMI Technical Staff:**
  - David DeSelms, Ronnie Minnick, James Biegler, Bryan Provine
- **Industry Partner:**
  - Custom Products Inc. provided seat frames and cushion test articles.

Questions?