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Forensic Engineering Investigation of an Alleged Plastic Chair Failure

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Abstract

Several identical one-piece molded plastic chairs were purchased by a mental hospital for use in an outdoor smoking area. The chairs were labeled as being for residential use. A hospital patient alleged that while seated in one of these chairs, the chair failed and he fell backward, striking his head and suffering injury. The subject chair did not show evidence of a failure that would correlate to the Plaintiff's allegation. Analysis and destructive testing was conducted on several of the remaining chairs, referencing the ASTM Standard Test Method for residential and nonresidential molded plastic chairs. Adverse expert opinions were also addressed.

Keywords

Forensic engineering, chair, plastic, molded, standard, residential

Introduction

A patient residing at a mental hospital stated that a plastic chair he was sitting in suddenly failed, leading to his injury. The one-piece molded plastic chair was among a dozen identical chairs provided by the mental hospital for patients using an outdoor smoking deck. The smoking deck surface was ceramic tile. The Plaintiff testified that he was seated normally with his elbows resting on the chair armrests, when suddenly one of the rear chair legs "broke" and he fell backward, striking his head severely. No significant observable injuries were noted by medical personnel following the alleged incident. The Plaintiff testified that he had been in the company of three other patients seated in a circle facing each other; these other patients were deposed as witnesses and confirmed his story to varying degrees. One additional witness provided a handwritten statement that she heard the Plaintiff discussing that he wanted to try and break one of the chairs – but this witness died before she could be deposed.

The chairs had been purchased by the hospital staff from a home-improvement store. Molded into the chair underside were the words "RESIDENTIAL USE ONLY". The label "manufacturer" of the chairs in fact bought them in bulk from another supplier, and had not participated in their development – the actual chair designer/manufacturer could not be found. Based on the "RESIDENTIAL USE ONLY" wording, the Plaintiff alleged that the hospital had provided inadequately strong chairs that were inappropriate for nonresidential use – implying that were the chairs of commercial quality, the incident wouldn't have happened. The Plaintiff weighed approximately 170 pounds.

Following the July 2000 incident, the hospital stored the evidence chair in an indoor closet. This author began work in the case in 2005 – the hospital made available four exemplar chairs nominally identical to the evidence chair. The exemplar chairs had been stored in an outdoor storage shed for nearly six years following the incident.

Inspection

- Inspection of the evidence chair (see Figures 1 & 2) revealed a one-piece plastic injection molded chair made of polypropylene. The chair had strips of packing tape across the armrests to prevent use, along with a sign warning against sitting in the chair. Three areas of the chair appeared to be fractured. One area was a portion of the right armrest vertical support; this fracture did not reveal visible evidence of significant molding or material flaws (see Figures 3 & 4). The other two broken features were tabs on the underside of the seat; these tabs were apparently intended to enhance the stability of the chairs when vertically stacked for storage (see Figures 5 – 8). Apart from these three areas, the chair did not reveal observable plastic deformation or fractures, and there was no evidence of a “broken” rear leg. As such, it was determined that exemplar testing would be necessary, as the evidence chair didn’t reveal obvious damage that would correlate with the events described by the Plaintiff.

Exemplar testing preparation

- The US standard for plastic chairs, ASTM F1561, was of use in determining acceptable performance for the subject chair design, and it was decided to base exemplar testing on the requirements of F1561. The general ASTM Technical Committee that deals with Consumer Products is F15, and the subcommittee that deals with these plastic chairs is F15.33, “Outdoor Plastic Lawn Furniture”. The subject F1561 standard was entitled “Standard Performance Requirements for Plastic Chairs for Outdoor Use”.



Figure 1
Evidence chair with fracture highlighted



Figure 2
Evidence chair left side



Figure 3
Fractured right armrest support

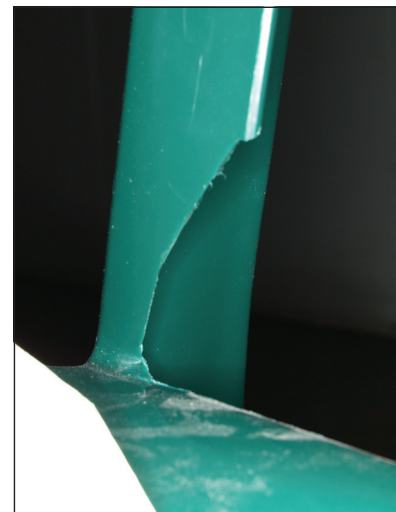


Figure 4
View of fracture

At the time of this 2005-2006 investigation, the 1996 version of this standard was applicable.

- The F1561 standard is stated as applying only to new chairs as manufactured; the fact that the subject and exemplar chairs had been in use for some time was considered acceptable. It was thought reasonable to assume that usage-related heat cycling, polymer aging, and the effects of oxidation, ozone, UV light, and humidity would make the subject and exemplar chairs weaker than new chairs.
- The standard defines two categories of chairs – residential use and nonresidential use. The tests for nonresidential chairs are more severe. Two sample “floor” surfaces were to be used in testing – tempered glass and plywood. Tempered glass was meant to simulate low-friction usage surfaces such as wet swimming pool decks, ceramic tile, vinyl composite tile, etcetera. Plywood was meant to simulate higher friction usage surfaces such as wooden decks and grass. Both test surfaces were composed of “layers” meant to impart some combination of resilience and rigidity.
- The low-friction test surface, per the standard, was to consist of (from top to bottom):
 - Tempered glass, 36 inches square by 0.38 inches thick
 - Polypropylene microfoam sheet, 36 inches square by 0.13 inches thick
 - AC grade exterior fir plywood, 36 inches square by 1 inch thick
 - PMMA (acrylic) plastic sheet, 36 inches square by 0.25 inches thick
- The high-friction test surface was to consist of (top to bottom)
 - AC grade exterior fir plywood, 36 inches square by 1 inch thick
 - PMMA (acrylic) plastic sheet, 36 inches square by 0.25 inches thick
- The specific tests to be accomplished by residential chairs, on first the glass and then the plywood surfaces, included the following:
 - Static loading: Apply a load of 300 pounds to the center of the seating surface for 10 seconds,



Figure 5
Bottom of evidence chair showing locations of broken underseat tabs



Figure 6 and 7
Broken underseat tabs



Figure 8
Exemplar chair left side

- withdraw for 10 seconds, and repeat this eight times. Then apply the load for 30 minutes, withdraw, and inspect for damage.
- Impact loading: Drop a 150 pound load onto the seat surface from 6 inches above the seat. Repeat nine times.
 - Rear leg test: Elevate the front legs on 4.5 inch high blocks and apply the 300 pound load to the seat for 60 seconds. Withdraw and inspect for damage.
- The specific tests to be accomplished by nonresidential chairs were identical in form to the tests for residential chairs, with the following exceptions:
 - Static loading: Use a 400 pound test load instead of 300 pounds.
 - Impact loading: Use a drop height of 8 inches for the 150 pound test load, instead of 6 inches.
 - Rear leg test: Use a 400 pound test load instead of 300 pounds.
 - The passing criteria for the F1561 testing were that the chair shall not “collapse” or display “visible evidence of structural damage” after undergoing all tests.
 - In addition to the materials needed for the two test surfaces, the following apparatus elements were needed:
 - A ballast bag for the static, impact, and rear leg test loads. See Figure 9.
 - 150 pounds of steel or lead shot for use in the ballast bag.
 - Additional weights to make up the needed 300 and 400 pounds of static test load. See Figure 10.
 - A mechanism for lifting and lowering the test loads.
 - A quick-release cargo hook (Peck & Hale H44-3 was chosen), to facilitate the impact tests.
 - As is the case with many standards, there were elements of the F1561 test procedures and apparatus specifications that were unnecessarily rigorous and impractical. Rather than attempt



Figure 9
Custom canvas ballast bag



Figure 10
Lead ingots in bucket atop ballast bag

to comply with all elements of the standard as written, a case document was prepared that outlined the issues and this author's chosen alternatives – test procedure issues were as follows:

- Withdrawal of test weight – item 6.3.3: After test loading, test weights were required to be removed within a short period of time – which would be difficult to do consistently without the use of pneumatic or hydraulic actuators on a specially built test fixture. For this case, a hydraulic engine hoist (used for vehicle servicing) was rented. As a longer duration of weight application provides more of a “worst case” test, for this case the weights were in place for the nominal duration and then removed as quickly as reasonably possible, using the hydraulic jack of the engine hoist.
- Impact test – item 6.4.2: In the dynamic impact (drop) tests, there was a requirement to start test weights 6" (or 8" for nonresidential chairs) above the center of the seat, with a tolerance of +/- 0.1" – this was unnecessarily narrow in range for a loaded canvas bag. Additionally, determining the center of a non-planar seat surface can be a subjective determination. For this investigation, the test weight was always at least 6" (or 8") above the approximate center of the seat surface.

Results from F1561 testing

Four exemplar chairs were tested; these were labeled A, B, C, and D. Each chair was inspected before testing for significant defects – none were found. All testing was done per the F1561 procedures as modified above.

- Chair A: This exemplar chair underwent the tests for residential chairs.

- Glass surface: Static, impact, and rear leg tests were without failure or significant permanent deformation. See Figures 11 – 13.

- Plywood surface: Static testing was without incident. Chair failed on first impact test, when the test weight broke through the seat pan and left side seat pan reinforcement (see Figure 14). No leg fracture occurred.



Figure 11 and 12
Chair A static load testing



Figure 13
Chair A rear leg test



Figure 14
Impact test failure of seat pan

- It is of note that Chair A had undergone an earlier, modified set of F1561 residential testing by this author prior to the author's obtaining the quick-release cargo hook and tempered glass surface. In this preliminary testing, acrylic sheet was used instead of the lower-friction tempered glass. For the preliminary impact tests, an engine hoist was used and the load was dropped as quickly as the hydraulic release valve (on the hoist) would allow. No chair failures occurred; it was determined that these testing compromises were unacceptably different from the F1561 requirements. As such, the tests were repeated (as described above) once the prescribed equipment was obtained – but this preliminary testing may have weakened Chair A.
- Chair B: This exemplar chair underwent the tests for nonresidential chairs.
 - Glass surface: The 400 pound static loading cycles were without incident, but the 30 minute static test resulted in the slow deformation of the legs into a rearward splayed position (see Figures 15 & 16).
 - Plywood surface: No testing was conducted due to the deformation of the legs.
- Chair C: This exemplar chair underwent the tests for residential chairs.
 - Glass surface: The 300 pound static loading cycles were without incident, but the 30 minute static test resulted in the slow deformation of the rear legs into a splayed position (see Figure 17). Note that the amount of deformation for this chair was greater than for the higher 400 pound loading of Chair B. This may be a function of greater foot “slippage” on the glass surface.



Figure 15 and 16

Chair B before and after 30 minute static 400 pound load



Figure 17

Chair C after 30 minute static 300 pound load

Additional tests

As the subject (evidence) chair exhibited broken underseat tabs, it was of interest to determine the loading necessary to break these tabs. Testing was done by stacking exemplar chairs B, C, and D, and applying F1561 loads.

- Chair C stacked on Chair B: residential impact tests (150 pound drop test from 6 inches above the seat pan)
 - Glass surface: Following the first impact, the front underseat tabs on Chair C were found to have broken in a manner consistent with the evidence chair. A second impact resulted in the fracture of the seat pan of Chair C (see Figures 18 & 19). Chair B was not damaged in this testing.
- Chair D stacked on Chair B: nonresidential static tests (400 pound test load)
 - Glass surface: Static loading did not result in breakage of the underseat tabs of Chair D, nor any other failure.



Figure 18
Stacked Chairs B and C

Adverse expert testimony

The Plaintiff hired a licensed Professional Engineer who specialized in forensic materials science and metallurgy. In that expert's Federal Rule 26 report, several opinions were offered:

- Adverse opinion 1: The evidence chair was not the “accident chair” because it didn't show damage consistent with the incident as described by the Plaintiff and witnesses.
 - This was not expressed as an objective statement that the evidence did not match the described incident – it was an assertion of evidence spoliation.
 - Because of this core opinion, the expert did not see a benefit to conducting any testing of the chair design. He was aware that relevant exemplars were available, and he stated that a chair successfully passing the F1561 testing would be an acceptable design.
 - The expert would expect to see permanent “white marks” from plastic deformation, and/or fractures, if the chair had failed in the manner described.
- Adverse opinion 2: The subject “residential only” chair was inappropriate for use at the hospital. And as the chair was intended for residential use, the fact that the Plaintiff was reported (by the one witness) to be trying to break the chair was not important.



Figure 19
Seat pan fracture on Chair C after impact test

Comparison of analysis results with case allegations

Addressing the allegations of the Plaintiff, deposed witnesses, and Plaintiff's expert, there were several hypotheses asserted, as follows –with this author's responses:

- Hypothesis 1: The evidence chair had a design defect that would affect all such chairs.
 - Such a defect would likely show up in the F1561 testing, which was appropriately challenging in ways relevant to the allegations. No observed failures of the evidence or exemplar chairs were consistent with a design defect that could have caused the incident as alleged.
- Hypothesis 2: The evidence chair had a manufacturing defect.
 - The three observed failures of the evidence chair (partially fractured armrest support and broken underseat tabs) were not the failures to be expected if the incident had happened as alleged. There were no broken legs or any evidence of sudden plastic-deformation-related collapse. Exemplar testing showed that rear leg plastic deformation happened gradually, when loaded well in excess of the Plaintiff's 170 pound weight.
 - The partial fracture of the evidence chair's armrest support did not occur in the other chairs during exemplar testing, and handling of the chairs did not reveal an obvious mechanism for this fracture to occur. Though in-depth material analyses of the fracture surfaces were not conducted, the fracture would not have been causative to the incident as alleged.
- Hypothesis 3: The evidence chair had a maintenance defect.
 - This type of one-piece plastic chair would require no actual maintenance, though periodic inspection could be appropriate, depending upon usage. Even if the hospital failed to find the three broken areas of the evidence chair during inspection, there still is no indication that these broken areas would have contributed to the incident as alleged.
- Hypothesis 4: The evidence chair was not the "accident chair" involved in the incident.
 - Within a few hours of the alleged incident, the hospital staff reportedly had identified the "accident chair" (with the help of witnesses) and put it in a storage closet. To the staff's knowledge, that was the evidence chair presented for inspection in 2006. The hospital, however, did not painstakingly photo-document or otherwise track every experience of the "accident chair" – but the Plaintiff had no tangible evidence that the "accident chair" was not the one presented for inspection.
- Hypothesis 5: The evidence chair was inadequate for the hospital's intended use.
 - The F1561 testing seemed a reasonable challenge of the subject types of chairs. The criterion of no "collapse" can be viewed in the context of dictionary definitions of "collapse", which typically include elements of suddenness or abruptness. Using such definitions, there was no

collapse of the exemplar chairs that would have led to a sudden rearward fall by a user – the rear leg deformations of Chairs B & C each occurred slowly over many minutes of testing. The criterion of no “structural failures” was met, with the exception of the fractured seat pans on Chair A and Chair C – and these failures are inconsistent with the incident as alleged. It is worth recalling that these chairs were tested over six years after manufacture, and the F1561 tests are intended only for new chairs.

- Though the F1561 residential test’s static loading magnitude could be approached by an atypically large user, foreseeable use would not likely result in a catastrophic failure consistent with the incident as alleged. The residential test’s impact loading did cause Chair A to fail, but the failure was not consistent with the Plaintiff’s allegations.
- It is difficult to determine whether the subject “residential only” chairs were technically inadequate for the hospital’s use. The F1561 tests were intended for new chairs, and it is possible that the subject chairs (when new) would have passed the nonresidential tests without failure. Merely being labeled “residential only” is not a defect in itself. However, it would have been advisable for the hospital to have purchased commercial-market chairs unless they somehow verified the adequacy of “residential only” chairs.

Case outcome

After several years of Plaintiff-driven continuances, the case settled without trial.

