

Residential Bunk Bed Child Entrapment Safety Test Methods

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Abstract: A human factors accident reconstruction was conducted to analyze the circumstances surrounding a residential consumer bunk bed death involving a two-year-old boy who became trapped between the upper bunk and the top rung of the ladder. An anthropomorphic child dummy and an ASTM bunk bed standard child torso test probe were used to analyze the flexibility of the bunk bed ladder brackets and the gap between the brackets and the upper bed frame that allowed the ladder to lift and tilt, creating a child entrapment hazard. The primary goal of this investigation is to identify alternative safety test methods and designs to reduce the risk associated with these types of injuries and to make consumer bunk bed designers, manufacturers, distributors, sellers, safety standard agencies, testing laboratories, furniture industry associations, consumer safety organizations, pediatricians, and users more aware of the bunk bed ladder tilting/repositioning child entrapment danger.

Keywords: Residential Bunk Bed, Child Entrapment Hazard, Safety Test Methods

1. Literature Review

Injuries associated with young children becoming entrapped between a residential bunk bed side ladder and the bed have been reported in the ergonomics in design literature (Pollack-Nelson, 2011). To further address child entrapment hazards between the ladder and the lower bunk bed structure in the United States, changes were made to the performance requirements of ASTM F1427 Standard Consumer Safety Specification for Bunk Beds in 2013 (U.S. CPSC, 2015). A new section titled Mattress Size and Fit (Lower Foundation) was added to the ASTM F1427-13 standard to address entrapment hazards between the mattress and additional components, such as a ladder, attached to the lower bunk. A corresponding section was also added to the Test Methods section of the ASTM F1427-13 standard to prescribe how to measure the gap between a mattress and an adjacent rigid structural component. The requirements for testing of openings in the lower bunk using the wedge block for neck entrapment were expanded from end structures to the entire boundary of the lower bunk. The section titled Ladders was expanded to address entrapment hazards in and around ladders by prescribing a testing procedure involving the use of the wedge block probe (simulating a child's torso) and the 9-inch diameter rigid sphere to gauge gaps in the bed structure (ASTM F1427, 2013).

Performance requirements to address entrapment hazards are also included in the international bunk bed safety standards (AS/NZS 4220, 2010; EN 747-1, 2015). European EN 747-1:2015 standard for bunk beds contains safety requirements for accessible gaps between the bunk bed ladder tread and any part of the bed frame (EN 747-1, 2015). Australia/New Zealand AS/NZS 4220:2010 standard for bunk beds includes a test method for the integrity of the ladder/access device attachment means on a bunk bed where specified forces are applied to dislodge the ladder/access device from its attachment position (AS/NZS 4220, 2010).

Consumer bunk bed inclined ladders are typically attached to the top bed rail by hooks positioned at the top of the ladder as shown in ASTM F1427-13 (ASTM F1427, 2013). However, the international patent literature discloses an invention for a bracket for mounting a bunk bed ladder from the bed rail of an upper bunk to prevent the ladder from tilting outward while climbing (Fredman, 1982). An objective of the Fredman patent invention is to provide a bracket structure for mounting a ladder on a bunk bed assembly which prevents the ladder from tilting outward and reduces ladder failure due to forces exerted when climbing the ladder, such as occurs when the ladder is attached to the bed rail by conventional hooks.

2. Residential Bunk Bed Child Entrapment Incident

On May 22, 2018, a two-year-old boy became trapped in a tight space between a consumer bunk bed upper bunk and the top rung of the ladder at his residence in Ohio. The two-year-old child's mother found her son facing away from the bunk bed with his torso against the ladder top rung, his head above the ladder top rung, and his feet below the ladder top rung. The



Figure 1. Incident Bunk Bed (Child Entrapment Gap Indicated by Red Oval)



Figure 2. Deformed Bunk Bed Ladder Bracket After Incident



Figure 3. Anthropomorphic Child Dummy Trapped in Gap Between Ladder Top Rung and Upper Bunk Structure

mother tried to pull her two-year-old child through the space between the upper bunk structure and the ladder top rung to free his trapped body. The child's body was tightly wedged and would not move. During the child's extraction from the bunk bed, the child's mother pulled on the child's body, the ladder moved and one of the ladder top metal brackets broke, and eventually the child's body released from the entrapment.

Figure 1 shows the subject bunk bed involved in the incident with the child entrapment gap indicated by the red oval. When the ladder feet are contacting the floor, there is a 2.1-inch (53.3 mm) gap between the ladder top rung and the upper bunk structure. The ladder is hooked onto the upper bed frame, and the two ladder metal hooks are attached to the upper bunk structure with screws. Figure 2 depicts the condition of the subject bunk bed ladder deformed brackets after the incident.

3. Accident Reconstruction

A systematic accident reconstruction method incorporating human factors and biomechanics (Knox, 2015) was performed and included using the subject bunk bed and an anthropomorphic child dummy to analyze how the child became entrapped during the incident. Figure 3A (left image) displays the anthropomorphic child dummy with its feet and lower legs situated in the gap between the ladder top rung and the upper bunk structure. While the ladder feet were on the floor, the gap between the ladder top rung and the upper bunk structure was too small for the dummy to enter (see arrows in Figure 3A). However, during the accident reconstruction, tilting of the ladder increased the gap between the ladder top rung and the upper bunk structure such that the anthropomorphic child dummy lowered into the gap. Figure 3B (right image) displays the anthropomorphic child dummy's torso trapped between the ladder top rung and the upper bunk structure in a similar position as described by the child's mother after the incident.

4. Testing

Tilt testing conducted using an exemplar ladder on the subject bunk bed indicated that the ladder began to lift from the floor at approximately 0.8 pounds of force applied at the ladder base. With the application of 7 pounds force to the exemplar



Figure 4. Exemplar Ladder Contacting Floor (Left Image) and Tilted (Right Image)

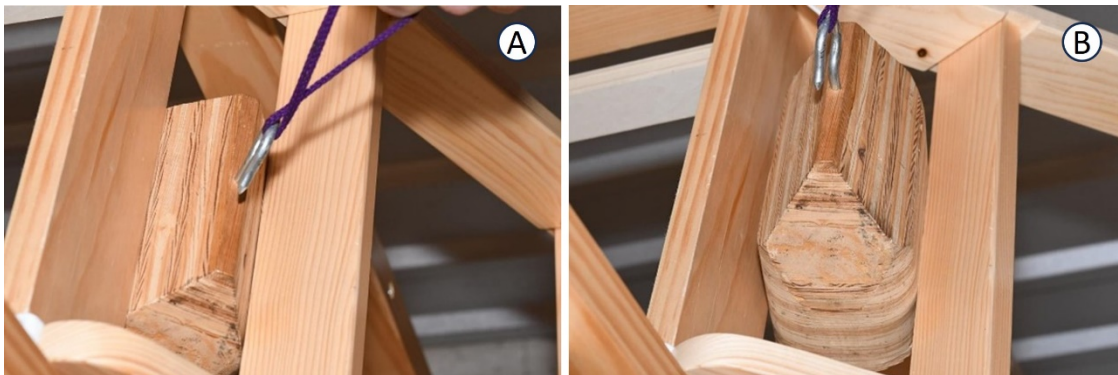


Figure 5. ASTM F1427 Test Wedge Pulled Through Exemplar Ladder

ladder base, the ladder tilted enough to increase the top opening enough to allow passage of the ASTM F1427 torso test wedge (3.5 inches / 88.9 mm). Figure 4 shows an exemplar ladder in a position contacting the floor (left image) and in a tilted position (right image). Figure 5A (left image) illustrates how the ASTM F1427 test wedge does not pass between the ladder top rung and the upper bunk structure from below with the ladder base contacting the floor. Figure 5B (right image) depicts the ASTM F1427 test wedge completely passing through the gap from below the gap with the ladder tilted after approximately 43 pounds force was applied to the test wedge.

5. Safety Standards Analysis

Based upon the test results from the exemplar ladder, the bunk bed involved in the subject incident failed to comply with the ASTM F1427-13 safety standard ladder requirements with respect to ladder repositioning or tilting, and complete

passage of the test wedge between the ladder top step and upper bunk boundary (ASTM F1427, 2013). Specifically, the incident ladder did not meet the requirements of ASTM F1427-13 section 4.9.1, which states that the ladder shall be attached in a manner that prevents inadvertent disengagement, repositioning, or tilting while in use. Also, the incident ladder failed to comply with the requirements of ASTM F1427-13 section 4.9.3, which states that there shall be no openings between the ladder step and the upper bunk boundary that allow complete passage of the wedge block unless they are large enough to permit the free passage of the 9-inch (230 mm) diameter rigid sphere. The flexibility of the ladder brackets and the gap between the ladder brackets and the upper bed frame allowed the ladder to lift and tilt, which permitted complete passage of the wedge block. Furthermore, the gap between the upper bunk structure and the non-tilted ladder top rung (2.1 inches / 53.3 mm) did not meet the requirements of EN 747-1:2015, which specify that the gap between any tread and any part of the bed frame shall be: a) less than 7 mm (0.28 inch); or b) at least 12 mm (0.47 inch) but not more than 25 mm (0.98 inch); or c) at least 60 mm (2.35 inches) but not more than 75 mm (2.95 inches); or d) at least 200 mm (7.87 inches).

6. Conclusions

Human factors analysis determined that children as young as two years of age will be capable of exerting enough force on the incident bunk bed ladder to create a potentially hazardous gap between the ladder top rung and the upper bunk structure (Brickman, 2002). Following the subject incident, the U.S. Consumer Product Safety Commission (CPSC) independently identified that the metal hook fastening the ladder to the top bunk bed frame can move away or detach from the bed frame when the ladder is lifted, causing the gap between the ladder step and bed frame to open wider than 3.5 inches (88.9 mm), posing serious child entrapment and strangulation hazards (U.S. CPSC, 2021). After the incident, the subject bunk bed manufacturer recall provided consumers with a retrofitted and reinforced ladder bracket to inhibit the repositioning and tilting of the ladder, which creates the serious child entrapment hazard (U.S. CPSC, 2021).

The primary goal of this investigation is to identify alternative safety test methods and designs to reduce the risk associated with these types of injuries and to make consumer bunk bed designers, manufacturers, distributors, sellers, safety standard agencies, testing laboratories, furniture industry associations, consumer safety organizations, pediatricians, and users more aware of the bunk bed ladder tilting/repositioning child entrapment danger. An industry survey revealed that there exist alternative residential consumer bunk bed designs that do not possess the gap child entrapment hazard between the ladder top rung and the upper bunk boundary (Julian Bowen Limited, 2014; Storkcraft, 2019). The present study showed that the current ASTM F1427-19 Standard Consumer Safety Specification for Bunk Beds (ASTM F1427, 2019) can be improved regarding the definition of ladder tilting/repositioning, specific dimensional requirements for the gap between the ladder top rung and upper bunk based on anthropometric child data, and ladder tilting test methods and requirements.

7. References

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