Shock Absorption Performance of Construction Helmets under Repeated Top Impacts

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Background

• Helmets are one of the important injury prevention strategies in constructions (Janicak 1998)

• Occupational Safety and Health Administration (OSHA) requires employers to ensure each employee wears a protective helmet when working in areas where there is a potential risk of falling objects (OSHA 2012)

• Construction helmets are not required to be tested under repeated impacts in current standards (ANSI 2014; BS 2012)
Background (cont.)

• Helmet manufacturers recommend the replacement of industrial helmets immediately after a significant impact (e.g., 3M 2011; Columbia 2018; MSA 2018; Bullard 2018)

Two questions:
• The magnitude of impact intensity that may cause structural deterioration of helmets has not been determined
• There is no experiment-based evidence to support this generally-accepted rule
Repeated helmet impacts are common in sports: e.g. football players experience 6.3 head impacts per practice; 14.3 per game; and 1,400 per season (Crisco 2010)

Previous studies have evaluated shock absorption performance of different sports helmets:
- Baseball helmets (Tomioka 2009)
- Equestrian helmets (Mattacola 2017)
- Hockey helmets (Pearsall 2005)
- American football helmets (Cournoyer 2016)
- Motorcycle helmets (Lam 2010)
- Alpine ski helmets (Swaren 2013)
Objective

• To evaluate the shock absorption performance of industrial helmets under repeated impacts

• To verify if it is safe to reuse a helmet that has been subjected to an impact
Method: Experimental set-up

- Helmet impact tests were performed according to the Type I impact protocol in ANSI Z89.1 standard:
  - Free-fall impactor (mass 3.6 kg) impacts onto the fixed helmet
  - A commercial drop tower test machine (H.P. White Laboratory, Street, MD, USA) was used in the tests
Method: Experiments

• A typical Type I* model basic construction helmet was used

• For each of the trials, a new helmet was impacted ten times at a predetermined drop height

• The tested helmet was then visually examined for structural damage after the tests

* Categorized according to ANSI Z89.1
Results: Peak impact force for the first impact

Top impacts according to ANSI Z89.1:

- Drop height = 1.54 m
- Max impact force < 4.45 kN
Representative time histories of the impact forces for low drop height (3-ft) and high drop height (5-ft)
Peak impact force as a function of impact number

![Graph showing peak impact force as a function of impact number. The graph includes lines for different impact heights: 0.30 m, 0.61 m, 0.91 m, 1.22 m, 1.52 m, 1.83 m, 1.88 m, and 2.03 m. The peak force values are marked at various impact numbers, with a notable peak at impact number 4.45.](image-url)
Peak impact force as a function of drop height
Results

• Visual examinations found no structural damage in the test helmets even thought the helmet shock absorption performance becomes very poor after repeated impacts
Discussion and Conclusion

• Our data suggest that acceptable shock absorption performance of a helmet is dependent on a critical drop height which we have designated *endurance limit*.

• For the tested helmet model, the *endurance limit* is represented by a drop height of approximately 1.22 m, which is equivalent to a potential impact energy of 43.1 J (with an impactor mass of 3.6 kg).

• The *endurance limit* represents a parameter of the shock absorption characteristics or the endurance for the helmet under repeated impacts.
Summary

• If a helmet receives repeated impacts of a magnitude greater than the endurance limit, it will experience cumulative structural damage with increasing impact number, resulting in a degradation in shock absorption performance.

• Repeated impacts smaller than the endurance limit will cause little change in helmet impact absorption performance.

• The proposed approach, if accepted by industry, will change existing test standards and will improve existing safety management practice regarding helmet replacement.
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