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

Background (cont.)

- 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

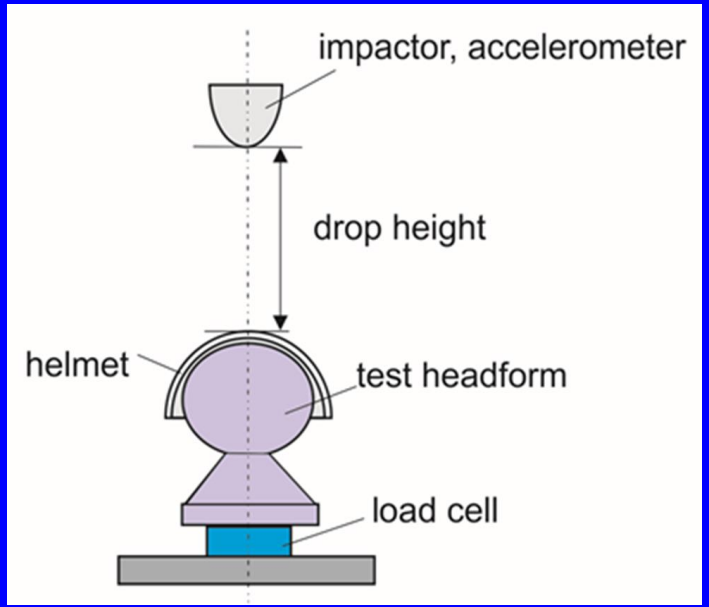
- To evaluate the shock absorption performance of industrial helmets under repeated impacts
- To verify if it is safe to reuse a helmet that has been subjected to an impact

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

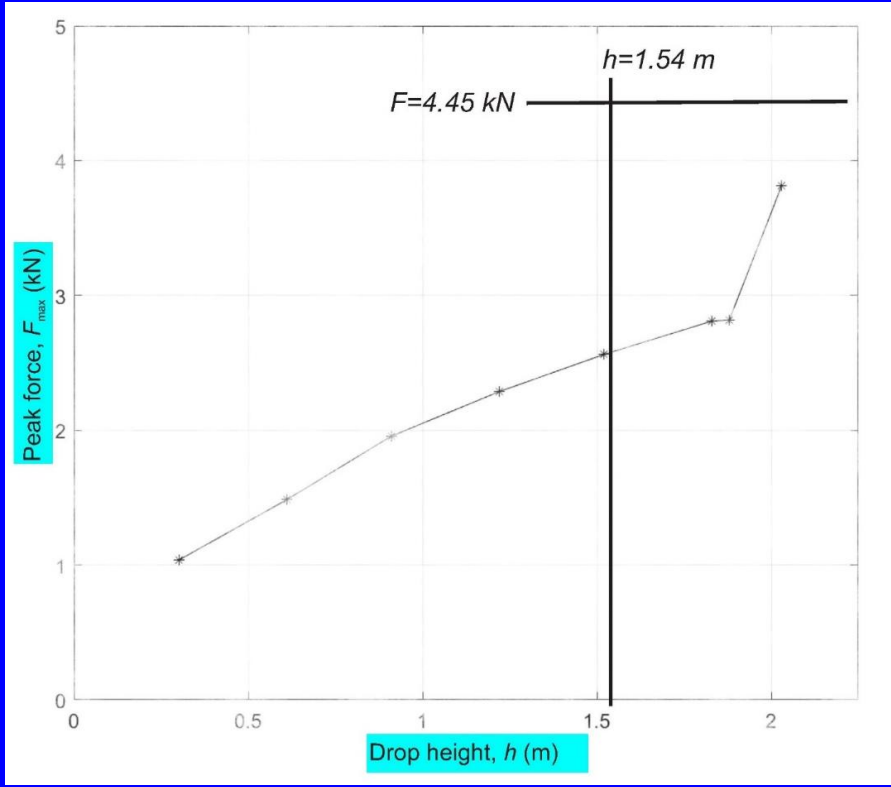


Method: Experiments

- 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

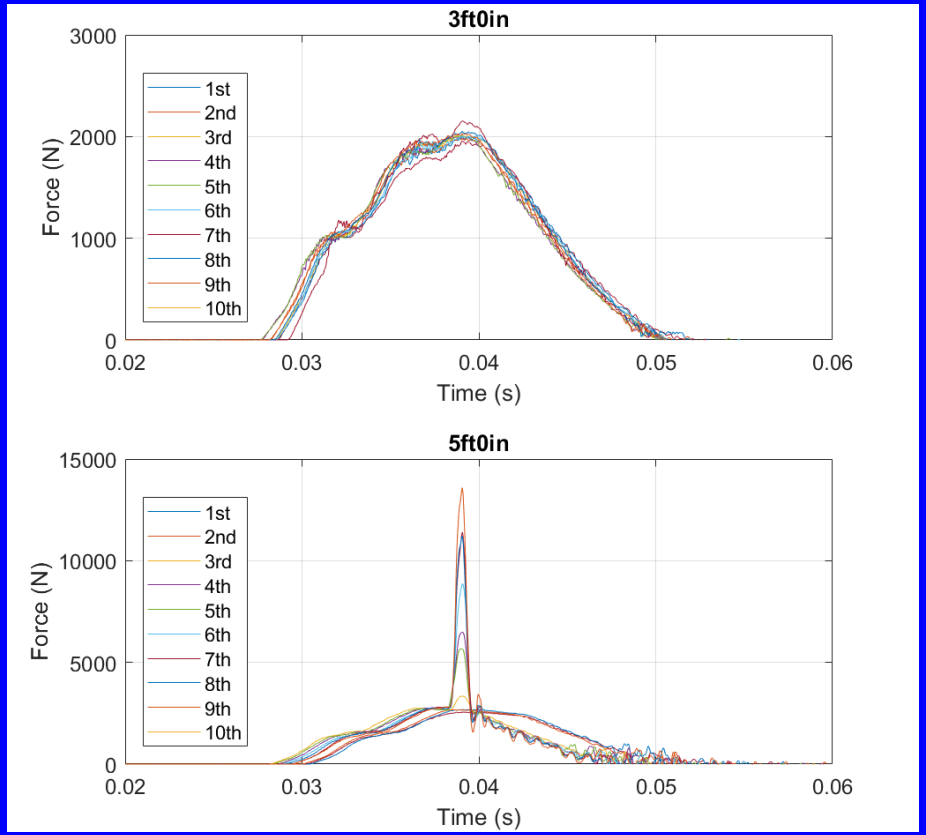
Results: Peak impact force for the first impact



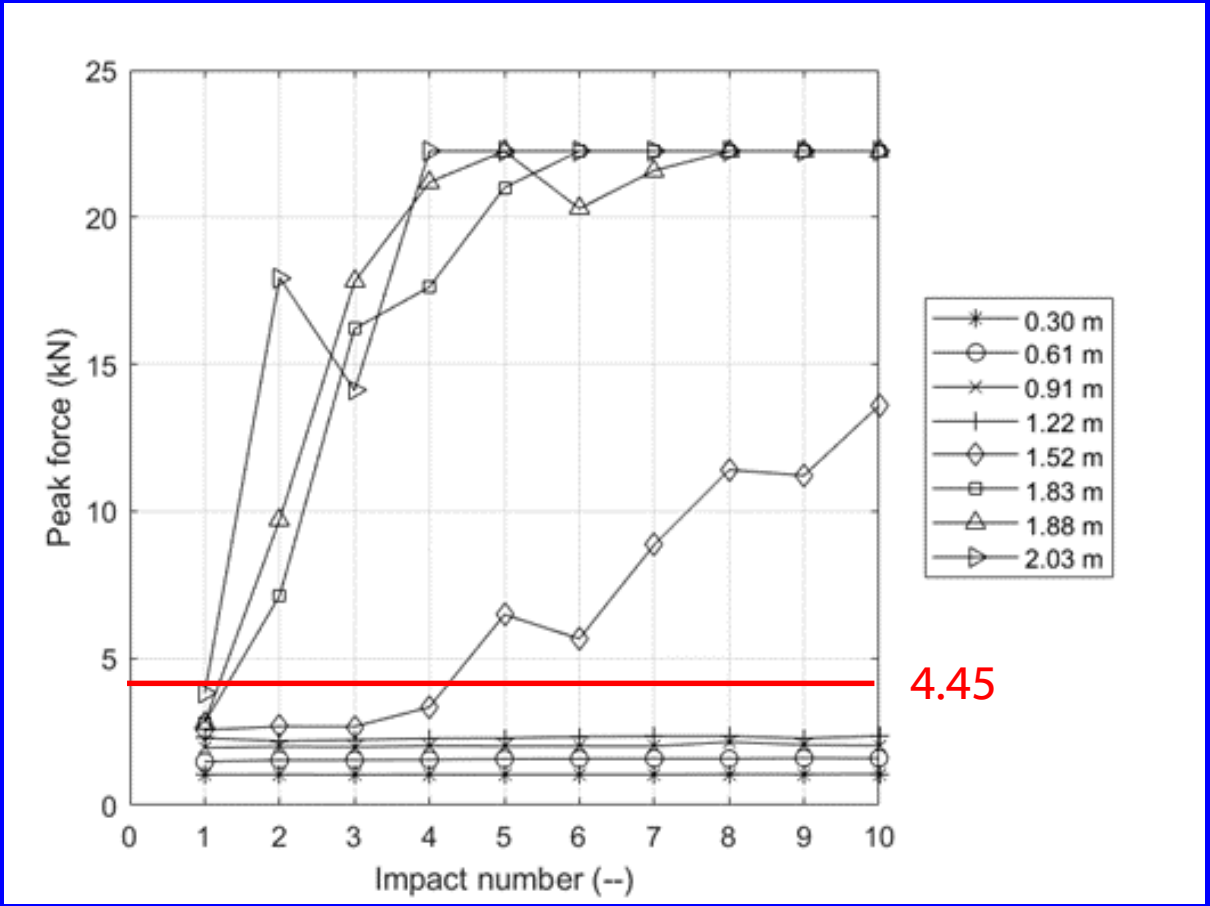
Top impacts according to ANSI Z89.1:

- **Drop height = 1.54 *m***
- **Max impact force < 4.45 *kN***

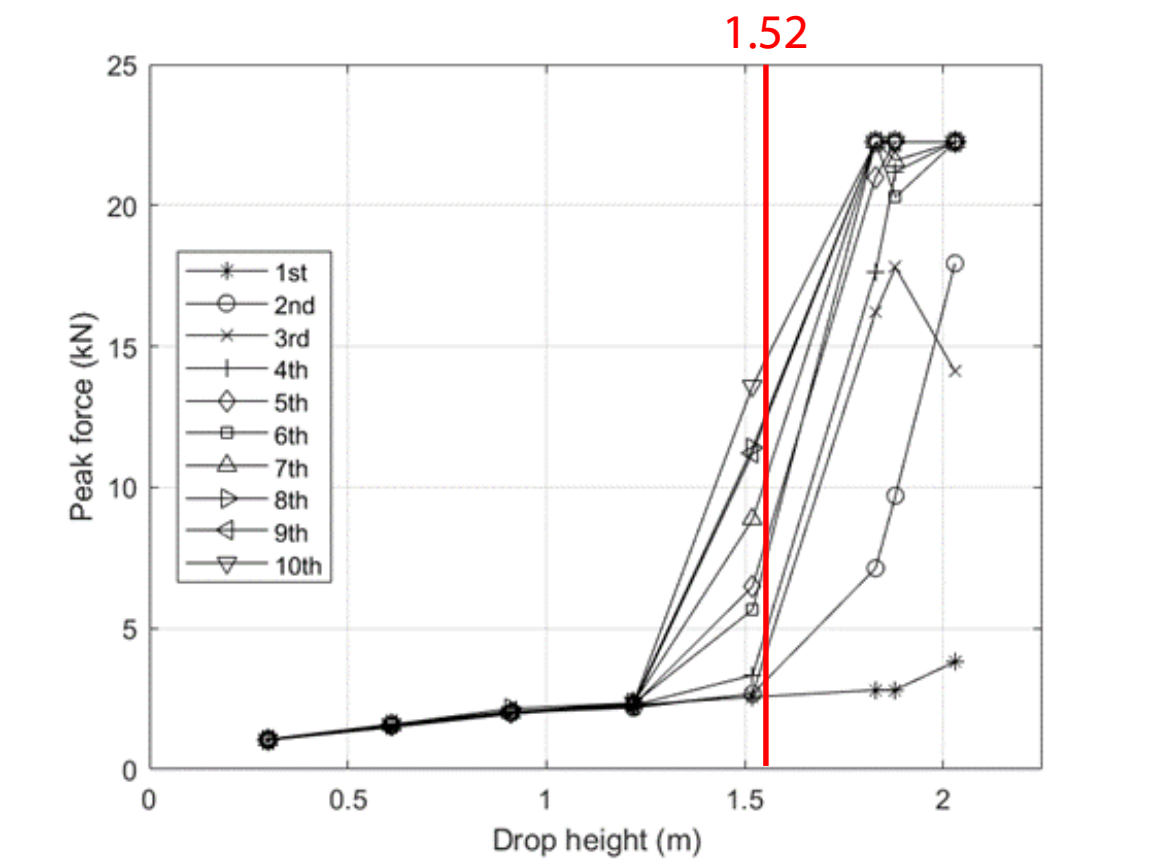
Representative time histories of the impact forces for low drop height (3-ft) and high drop height (5-ft)



Peak impact force as a function of impact number



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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Christopher S. Pan, Ph.D., CPE
NIOSH/CDC
1095 Willowdale Rd., MS-807
Morgantown, WV 26505

304-285-5978
304-285-6047 (fax)
cpan@cdc.gov

Thank You For Your Attention !

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Evaluation of the shock absorption performance of construction helmets under repeated top impacts

John Z. Wu, Christopher S. Pan*, Bryan M. Wimer

National Institute for Occupational Safety and Health, Morgantown, West Virginia, USA

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ABSTRACT

It is accepted in industries that an industrial helmet should be disposed of when it is subjected to a significant impact. There is no scientific evidence that supports this well-accepted belief. The current study was intended to evaluate the shock absorption performance of industrial helmets under repeated impacts. Common industrial or construction helmets are categorized as Type I according to ANSI Z89.1 and they are designed to mainly protect top impacts. A representative basic Type I construction helmet model was selected in the study. Helmets were repeatedly impacted ten times using a commercial drop tower tester with an impactor (mass 3.6 kg) at different drop heights from 0.30 to 2.03 m. A total of 80 impact trials were performed in the study. The relationships of the transmitted force with the drop height and with impact number were analyzed. A new parameter – the endurance limit – was proposed to evaluate the shock absorption performance of a helmet. The helmets were observed to experience cumulative structural damage with increasing impact number, resulting in a degrading shock absorption performance, when being impacted repeatedly with magnitudes greater than the endurance limit. Repeated impacts with magnitudes smaller than the endurance limit did not cause measurable cumulative structural damage to the helmets in our study.

1. Introduction

It is well recognized that traumatic brain injury (TBI) is a leading cause of death and disability among persons in North America [1]. Approximately 7.3% of TBI cases identified from the Ontario Trauma Registry were work-related [2]. Based on a review of coroners' records, about half of all workplace fatalities in Ontario were associated with TBI [3]. Work-related traumatic brain injury (WrTBI) accounted for approximately 20% of traumatic occupational injuries and 60% of work-related deaths in Washington State [4]. WrTBIs have been identified as one of the most serious workplace injuries among all work-related injuries in the United States from 1998 to 2007 [5]. Most of WrTBI cases occurred in the construction industry [6,7]. Streets construction and heavy construction trades have been identified as at the greatest risk for occupational fatalities due to impact-related head injuries [8]. Compared with other types of injuries, WrTBIs are much more likely to result in disability and death [9]. Industrial or construction workers who were wearing safety helmets at the time of a fall were less likely to sustain intracranial injury compared with workers not wearing a safety helmet [2]. The use of helmets was considered as one of the important prevention strategies in constructions [8]. Occupational Safety and Health Administration (OSHA) regulations for the construction industry require that employers shall ensure each employee wears a protective helmet when working in areas where there is a potential for injury to the head from falling objects [10]. Since the shock performance is the most important parameter for a helmet, there are strict regulations for the impact tests in different international

* Corresponding author at: NIOSH, 1095 Willowdale Road, Morgantown, WV 26505, USA.
E-mail address: cpan@cdc.gov (C.S. Pan).

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