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Shock Absorption Performance of Construction Helmets under Repeated Top Impacts

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Abstract: The use of helmets is considered as one of the important prevention strategies in construction to reduce the work-related traumatic brain injury risk. It is accepted in industries that an industrial helmet should be disposed of when it is subjected to a significant impact. However, there is no stringent experimental evidence that indicates that the shock performance of an industrial helmet will deteriorate in repeated impacts. The current study was intended to evaluate the shock absorption performance of industrial helmets under repeated impacts. Repeated impact tests were performed using a commercial drop tower tester with an impactor (mass 3.6 kg) at eight different drop heights from 0.30 to 2.03 m. At each of the eight drop heights, the helmets were repeatedly impacted ten times. The relationships of the peak 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.

Keywords: Construction Helmet, Top Impact Tests, Impact Force, Repeat Impacts

1. Introduction

The use of helmets is considered as one of the important prevention strategies in constructions (Janicak 1998). 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 (OSHA 2012). Since the shock performance is the most important parameter for a helmet, there are strict regulations for the impact tests in different international standards (ANSI 2014; BS 2012). However, it is not required in any standards to test a helmet with repeated impacts. The shock absorption performance of an industrial helmet under repeated impacts has not been analyzed. Although it is not regulated by OSHA or in test standards, helmet manufacturers [e.g., 3M Occupational Health and Environmental Safety (3M 2011), MSA Safety (MSA 2018), Columbia Safety and Supply (Columbia 2018), and ED Bullard Co (Bullard 2018)] recommend the replacement of industrial helmets immediately after a *significant* impact. However, the magnitude of the impact intensity that may cause the structural deteriorations of helmets has not been determined. There is no experiment-based evidence in the literature to support this generally-accepted rule. The purposes of the current study were to evaluate the shock absorption performance of industrial helmets under repeated impacts and to verify if it is safe to reuse a helmet that has been subjected to an impact. The knowledge obtained in our study would be essential to improve the current safety management in industries.

2. Methods

Helmet impact tests were performed according to the Type I impact protocol in ANSI Z89.1 standard (ANSI/ISEA Z89.1, 2014): the free-fall impactor (mass 3.6 kg) impacts onto the fixed helmet (Pan et al. 2019; Wu et al. 2018), as illustrated in Fig. 1.

One representative off the shelf Type 1 construction helmet model was used in this study. The Type I helmet is designed to protect from top impacts by a dropped object. A commercial drop tower test machine (H.P. White Laboratory, Street, MD, USA) was used in the tests. A force sensor installed at the base of the headform was used to measure the forces transmitted to the headform. An accelerometer installed within the impactor was used to measure the acceleration of the impactor during impacts. Both force and acceleration data were collected at a sampling rate of 25 kHz. A typical, basic construction helmet model, which is categorized as Type I helmet according to ANSI Z89.1, was used in the current study. For each of the trials, a new helmet was impacted ten times at a predetermined drop height; the helmet was then visually examined for structural damage after the tests.

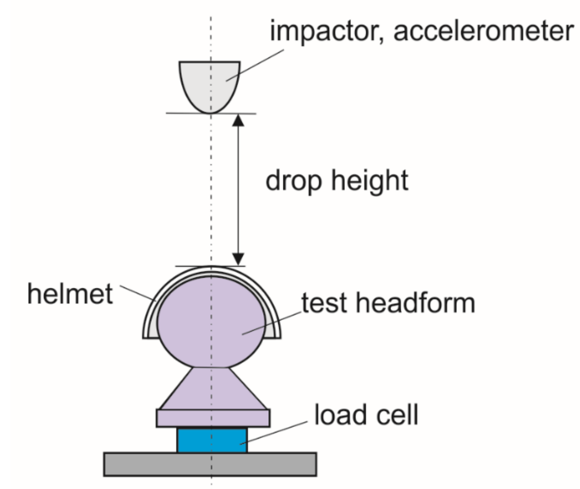

Figure 1. Schematics of test procedure.

3. Results

The peak transmitted forces as a function of the drop height, and as a function of impact number for eight drop heights are shown in Fig. 2A and 2B, respectively. For the tests with drop heights from 0.30 m to 1.22 m, the peak transmitted force and impact absorption coefficient change little with the impact number; and the transmitted force (Fig. 2A) is well below the maximal acceptable value of 4.45 kN as designated in ANSI Z89.1. When the drop height is greater than 1.52 m, the peak transmitted forces increase with increasing impact number. The transition drop height is around 1.52 m for this type of helmet. For the test with a drop height of 1.52 m, the peak transmitted force is within the acceptable range for the first four impacts, and then increases, with increasing impact number, above the acceptable force value (for impact number > 4). Our results show that 1.22 m is a critical drop height; and we name it as the *endurance limit*. It is clear that the peak transmitted forces (Fig. 2B) change little with the increase in impact number for drop heights less than the endurance limit. For drop heights greater than 1.52 m, the peak transmitted forces increase with increasing impact numbers.

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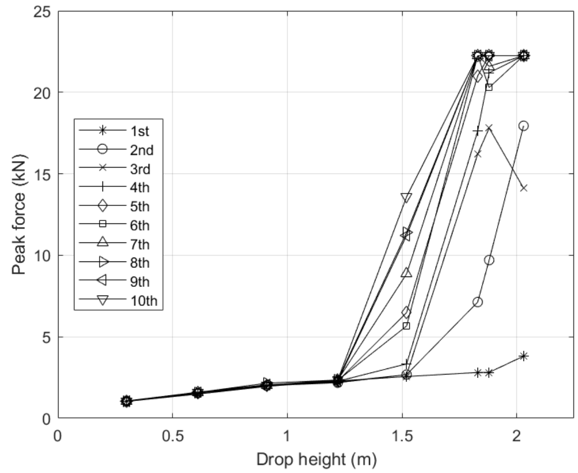

Figure 2a. The peak transmitted forces as a function of the drop height for repeated impact tests at eight different drop heights.

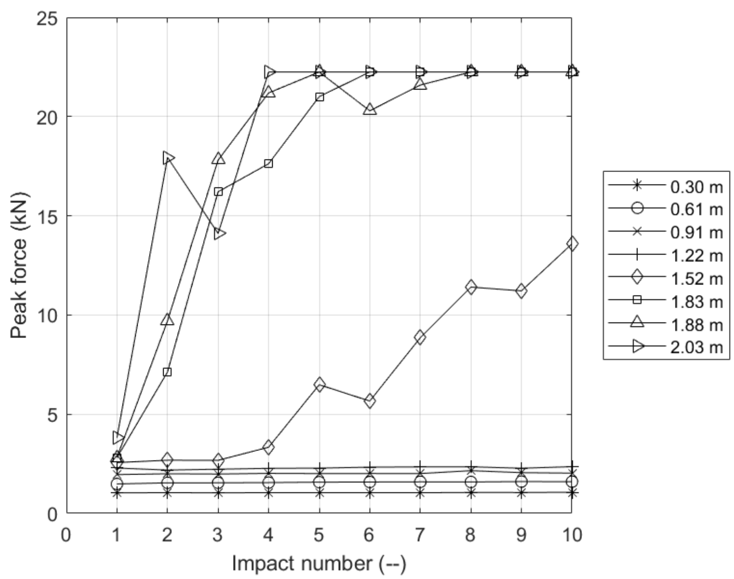

Figure 2b. The peak transmitted forces as a function of impact number for repeated impact tests at eight different drop heights.

4. Discussion and Conclusion

Our results suggest that the shock absorption performance of a helmet is dependent on a parameter -- the critical drop height -- or endurance limit. For the tested helmet model, the endurance limit is at 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. 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. In other words, if an industrial helmet is subjected to an impact that is greater than the endurance limit, the helmet's shock absorption performance

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will be compromised and the helmet would not be safe to use anymore. The proposed approach, if accepted by industries, will conceptually change existing test standards and will improve the existing safety management practice.

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6. Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

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