Development of an Industry-Relevant Oblique Impact Testing Protocol for Industrial Helmets

Sofia Cecić[a], Peter Cripton[a]

Orthopaedic and Injury Biomechanics Group[a], School of Biomedical Engineering and Depts. of Mechanical Engineering and Orthopaedics, University of British Columbia, Vancouver BC, Canada

Traumatic Brain Injury (TBI) is a major occupational safety concern, with approximately 17.9% of all TBIs being work-related (wrTBIs)[1]. Falls are the leading mechanism of wrTBI, responsible for 68% of cases, with construction workers disproportionately affected[2,3]. Despite the prevalence of falls, current industrial helmet standards, such as ANSI Z89.1, primarily test Type 2 helmets (those designed to attenuate blunt impact) for linear impacts from a low fall height of approximately 0.6 m and for penetration of simulated falling objects[4]. This fails to account for the high fall heights and oblique impacts and associated rotational forces which are key contributors to fall-related TBIs[5,6]. The objective of this study is to develop an industry-relevant test plan to evaluate the oblique impact performance of Type 2 industrial safety helmets, addressing critical gaps in industrial helmet safety standards.

There have been recent attempts to address these standardization gaps by introducing oblique impact testing for industrial helmets[7]. However, the impact velocities and angles used in these studies were derived from sports helmet testing and may not accurately represent real world industry fall scenarios. Workplace injury data in this study was extracted from the *Census of Fatal Occupational Injuries (CFOI)* from the *US Bureau of Labor Statistics* database as well as the *Occupational Safety and Health Agency's* (OSHA) *Severe Injury Reports* (SIR). The highest proportion of non-fatal TBIs occur from falls of 3.5-5 meters, while fatal TBIs are most common from falls of 5 meters and above[2,8–10]. Further, among industrial workers, roofers face the highest risk of fatal falls with over ten times the combined rate for all other construction occupations[2]. This is noteworthy because, depending on the worksite, roofers may not be required to wear helmets in all contexts in which they work. A study by Yu et. al used simulations to derive head impact speed, angle, and location across various fall scenarios representative of industrial injuries[11]. The study found that falls from 4 meters typically result in impact velocities above 8m/s, which is significantly higher than those used in current industrial helmet testing protocols.

Based on previous studies and existing workplace injury data, our objective is to design a test series consisting of several representative impacts for Type 2 industry helmets under conditions representative of real-world industry falls. While analysis is ongoing, we have identified several critical fall scenarios (Table 1) that may be included in our test series. Impact parameters will be chosen with regards to the specific occupation and injury severity of interest. Future work will focus on refining test methods and equipment specifications. By incorporating construction-relevant fall conditions into helmet evaluations, this study aims to establish more representative testing protocols, improve safety standards, and ultimately enhance worker protection in the construction industry.

Table 1. Key impact parameters by occupational group, injury severity, incidence and fall source.

Occupation	Source	Incidence (% of total)	Height (m)	Speed (m/s)	Angle (°)	Location on Head
Non-Fatal						
General Construction	Ladder *(Backward)*	37%	1.8[12]	3.88[12]	35[12]	Rear
			< 2	7.5	83	Rear, Top
	Scaffold *(Backward)*	8.8%	3.5 - 5	9.7	87	Rear, Top
Roofer	Roof *(Forward)*	6.8%	3.5 - 5	8	80	Front
	Roof (*Backward)*		3.5 - 5	9.7	87	Rear, Top
Fatal						
General Construction	Ladder *(Backward)*	24.2 %	3.5[11,13]	9.5	87	Rear, Top
			3.5 - 5	9.7	87	Rear, Top
	Scaffold *(Backward)*	14.7 %	9 +	9.7 +	87 +	Rear, Top
Roofer	Roof *(Forward)*	32.0 %	5 - 6	8	87 +	Front, Top
	Roof (*Backward)*		5 - 6	9.7 +	87 +	Rear, Top

Note. Data for impact speed, angle and location from Yu et. al, and data for height and incidence of non-fatal and fatal falls from OSHA SIR[10], and CFOI[2] respectively unless otherwise cited.

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