

Recommendations for Improving Hard Hat Safety

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In the construction industry, hard hats are ever-present but often neglected. Workers expect a hard hat to save them from injury if an accident occurs, but they pay little attention to hard hat maintenance. Said inattention can lead to a false sense of security and increase the potential for injury. This research seeks to establish the seriousness of the issue. First, baseline maintenance requirements are established by cataloging major hard hat manufacturers' maintenance and replacement suggestions plus how those suggestions are communicated to the wearer. Next, an online survey of commercial contractors in North Carolina is used to assess the industry's awareness of and planning for these requirements. Finally, in-person worker interviews, including examination of the workers' hard hats, demonstrate workers' knowledge of and adherence to the maintenance requirements. The paper concludes with several suggestions for manufacturers, contractors, and workers to improve the situation. This research should raise awareness of the issue and serve as a wakeup call for the construction industry.

Keywords: Construction Industry, Safety, Injuries, Protective Equipment, Prevention

Introduction

The hard hat is practically synonymous with the construction industry. More than any other piece of Personal Protective Equipment (PPE), the hard hat represents the industry. When the public thinks of construction, they think of hard hats. The United States Occupational Health and Safety Administration (OHSA) states e*mployees working in areas where there is a possible danger of head injury from impact, or from falling or flying objects, or from electrical shock and burns, shall be protected by protective helmets* and those helmets *shall meet the specifications contained in American National Standards Institute, Z89.1-1969, Safety Requirements for Industrial Head Protection (1926.100(a) and (b))* (osha.gov).Yet, due in part to its ever-present and deceivingly low-tech nature, the hard hat is often overlooked especially when it comes to its upkeep.

Hard hats protect the wearer via the *rigid shell that resists and deflects blows to the head and a suspension system inside the hat that acts as a shock absorber* (hard hats.4ursafety.com). It is important to understand that both parts act together to ensure safety. The shell acts as a shield against bumps and scrapes and helps absorb the impact of minor strikes. The suspension provides space for the shell to move without hitting the wearer's head. Using either four or six attachments (called tabs or pins), the suspension acts as a shock absorber distributing the force of a blow evenly around the wearer's head. The hat must be securely placed on the worker's head to function properly. This is achieved by an adjustable head strap with some manufacturers using a ratcheted dial while others use slotted tabs. The height of the hat can also be adjusted via slotted tabs.

Although hard hats come in an almost unlimited variety of colors and shapes they are classified into two primary types. *Type I hard hats are intended to reduce the force of impact resulting from a blow only to the top of the head and Type II hard hats are intended to reduce the force of impact resulting from a blow which may be received off center or to the top of the head. A Type II hard hat typically is lined on the inside with thick high density foam* (coopersafety.com). The top hard hat manufacturers suggest their products be replaced entirely every five years (sooner if damaged). Further, they suggest a hard hat's suspension system be replaced more frequently (every 12 months) due to the addition of hair and body oils which play a factor in the breakdown of the material's strength. Anecdotal research indicated that many workers in the construction industry were not aware that hard hats needed to be maintained with many workers questioned having no idea that hard hats ever expired.

Research Question

This lack of awareness prompted the research question: Is the NC commercial construction industry endangering its workforce by not adhering to manufactures' recommendations regarding hard hat maintenance? Note: Neither residential construction companies nor its workers were included in this research.

Literature Review

The earliest published study regarding hard hats, or protective helmets as they are called in the study, was published in 1974 by the National Institute of Occupational Safety and Health (NIOSH). The study explores helmet types, composition, and standards of the day, and included extensive discussion of impact tests performed to determine how well helmets actually protect their wearers. In 1987, Gilchrist and Mills published their first research of impact tests conducted on hard hats. They concluded that strikes to the top of a helmet could be absorbed appropriately, but strikes to the side were dangerous to the wearer (Gilchrist and Mills, 1987). Since that time, the duo have published additional papers critiquing and expanding upon their earlier work and calling for more attention to lateral strikes to a worker's head (Mills and Gilchrist, 1993). More recent studies such as Xiaowei's study of hard hat use in Hong Kong, performed impact tests to help explain the physics of hard hats and how they protect their wearers (Figure 1).

Several authors discuss OSHA's regulations on hard hats including Sutcliffe (2002), Stromme (2011), Lloyd (2007), and Bacon (2001). OSHA of course has several publications on the subject including OSHA 3151-12R 2003 which covers the types of workers needing hard hats, the various types of hard hats, and suggested inspection and replacement guidelines. In 2007, the Department of Labor issued a clarification of OSHA regulations stipulating that employers pay for their workers' PPE.

Figure 1: The Physics of a Hard

Note: Xiaowei, Chen. (1999). Safety Assessment of Hard hats Used in Hong Kong. Hong Kong University of Science and Technology.

Also relevant to the conclusions of this paper is the literature regarding the impact of proper training on safety results. Kaskutas, Dale, Nolan, Patterson, Lipscomb, and Evanoff (2009) clearly demonstrate a positive relationship between training and the proper use of PPE including hard hats. Sutcliffe (2002) quotes a large contractor who credits the proper use of hard hats to its training program. A Survey on the Usage of Hard Hats in Hong Kong Construction Sites found that *most construction workers lack the training of the safe handling of hard hats, and they*

do not have enough knowledge on the maintenance and regular replacement of hard hats (Pg 7). Hintch (2006) recommends discussing hard hat safety and maintenance with workers two or three times per year.

Seeing the connection between training and accidents, the 2008 National Occupational Research Agenda (NORA) included four strategic goals (11.1, 11.2, 11.3 and 11.4) to improve safety and health training and education in construction. Finally, Stromme (2011) discusses OSHAs training requirements and Sacks, Perlman, and Barak (2013) summarizes the situation best by saying *construction workers' ability to identify and assess risks is acquired through training and experience and is among the key factors that determine their behavior and thus their safety.*

Most directly associated with the topic of this paper, significant information and literature exists concerning hard hat maintenance. Beginning with OSHA itself, which specifies that hard hats must be provided by the company and that *workers working in areas where there is a possible danger of head injury from impact, or from falling or flying objects, or from electrical shock and burns, shall be protected by protective helmets* (OSHA.gov 1926.100(a)) but interestingly OSHA does *not call for a particular service life of a hard hat* (Sutcliffe, 2002, Pg 2). Lloyd (2007) points this out as well (Pg 1).

The service life of a particular hard hat is defined by the manufacturer and is dependent on several factors including:

- Exposure to Ultraviolet light (UV)
- Temperature and humidity extremes
- Exposure to harsh chemicals including paint and adhesives
- Damage from being dropped, strikes, etc.

According to all manufacturers and authors, a hard hat that has been involved in any kind of accident or strike should be replaced immediately. Any nick, crack or abrasion could potentially diminish its protective integrity. Similarly any damage to the suspension system, including stretching, fraying or tearing could jeopardize the wearer. According to Bacon (2001), a hard hat should also be replaced if dropped from a height of more than eight to ten feet. Many authors address general replacement guidelines. *Hard hats have a reasonable service life…however, useful life is not indefinite* (Bacon, 2001, Pg 2). *Many workers don't realize that their hard hats do wear out and they should be replaced* (Hintch, 2006, Pg 1). *Workers who use gloves…can obviously see and feel the need for new gloves… Workers may be wearing a hard hat well past its useful life without even knowing it* (Lloyd, 2007, Pg 1).

Most authors including Bacon (2001), Lloyd (2007), Peters (2012), Hintch (2006), and Rowlinson (2012) address the useful service life of a hard hat shell and agree that the general life span is five years. This matches manufacturers' recommendations. There is less agreement regarding the replacement of suspension systems. Bacon (2001) suggests replacement at *signs of wear* (Pg 2) while Lloyd (2007) and Rowlinson (2012) recommend annual replacement (as do most manufacturers). Bacon (2001) comments that suspension systems are *too often overlooked* (Pg 2). Smith (1994) states users should *examine the shell for discoloration, a chalky look or feel, hairline cracks, or brittleness before and after every use. The suspension system should be examined for frayed or cut straps and for cracks and flexibility in the crown strap* (Pg 3). Bacon (2001) also suggests inspecting both components of the hard hat and adds looking for *nicks, dents or gouges* in the shell (Pg 1) and key slot tightness for suspensions (Pg 2). Lloyd (2007) concurs as do Peters (2012), Rowlinson (2012), and Garvey (2009). In addition to inspections, a simple field test is suggested by Bacon (2001). *Compress the shell inward from the sides about one inch with both hands, then release the pressure without dropping the shell. The shell should quickly return to its original shape, exhibiting elasticity. There should be no residual deformation. Compare the elasticity of the sample with that of a new shell. If the sample does not exhibit elasticity similar to that of a new shell, or if it cracks because of brittleness, it should be replaced immediately* (Pg 2).

Since no research was found directly linking accidents to outdated hard hats, further research in this area is recommended.

Research Methodology

Three main sets of data needed to be collected to properly assess whether construction workers in North Carolina were being exposed to unnecessary danger by wearing outdated hard hats or failed to maintain their hard hats as they should:

- What hard hat manufacturers recommend regarding their products
- Whether construction companies train their workers on manufacturers' recommendations and have programs in place to comply with those recommendations
- Whether workers themselves are aware of and abide by those recommendations

Manufacturers' data was obtained from the manufacturers themselves through their company websites, direct contact with the company, or by procuring a new hard hat and examining the information contained with the new helmet. Information regarding construction companies' policies, training, and replacement programs was obtained via an online survey. Data about workers' actual use and care of their hard hats was collected through in-person interviews. Details for each follow.

Manufacturers' Data

To determine whether companies and workers are abiding by manufactures' recommendations, those recommendations first had to be established. Although hard hats are manufactured by many different companies, in the US there are five primary brands: MSA, Bullard, North/Fibre-Metal, 3M, and Pyramex. Each has a complete line of hard hats including various shapes, colors and costs. For this study, the most prevalent model was selected and information was obtained regarding maintenance recommendations and warranty period (Table 1).

Table 1. Maintenance Information from Primary Hard Hat Manufacturers

Manufacturer	Model	Suggested Replacement Frequency		Warranty Period
		Whole Hat/Shell	Suspension System	
Bullard	S61	Every 2 -5 years (check company policy)	Every 12 months	2 years from date of manufacture
MSA	V-Guard	No more than 5 years of use	No more than 12 months of use	1 year from purchase
Fibre-Metal/ North	A79	Not specified on wrapping, 5 years stated per separate sheet	Not specified on wrapping, 1 year stated per separate sheet	Not specified
3M	H-700	Every 2 -5 years	Every 12 months	Not specified
Pyramex	Ridgeline	5 years from manufacture	Not specified	Not specified

A new hard hat was obtained from the top manufacturers to determine the exact state of the device when received by a worker. In all cases instructions were included on the plastic wrapping enclosing the hat in multiple languages: English, Spanish and French. One manufacturer included additional languages. Most packaging included legalistic warnings that all instructions should be read and followed with one indicating that only the wearer of the hat should remove it from its wrapping. Most of the written instructions included details for care and cleaning, daily inspection, and replacement timeframes.

Company Data

Next, data was collected to determine if hard hat replacement was being taken seriously at an organizational level. An online survey was conducted to obtain data regarding construction companies' awareness of manufacturer replacement recommendations, training of their workers on hard hat maintenance, and whether they have programs in place to replace hard hats and suspensions as recommended.

Several questions were composed to collect the desired data, both demographic (to understand the types of companies responding) and specific to the topic. They were vetted, adjusted and narrowed to the best nine. Qualtrics, the ECU recommended application for online surveys, was used to perform the survey. One hundred and seven surveys were emailed to recipients randomly selected from a roster of Carolinas Associated General Contractors (AGC) members in the Building category (not Heavy Highway or Utility) across North Carolina. Recipients were asked to complete the survey within two weeks. Two surveys/emails were returned as undeliverable. Ten responses were completed in the first hour. Reminders were sent to recipients who had not responded in the first ten days.

Worker Data

In-person worker interviews were conducted at four construction sites in Durham, the Research Triangle Park (RTP), Charlotte, and Harrisburg, NC representing various types of commercial buildings: high-rise residential, healthcare, pharmaceutical, and entertainment. The sites were managed by three different general contractors/construction managers and were at varying stages of the construction cycle so all types of subcontractors were represented in the study. Two projects were in the early stages of construction so civil, foundation, and steel workers were interviewed, while the other two projects were farther along so finish workers such as painters, drywallers, and cleanup crew members were interviewed. Workers representing a mix of genders, ages and ethnic backgrounds were interviewed. The target of interviewing 20-25% of the workers present on each site was achieved. The interviews were set up in advance with the project's project manager and superintendent. To avoid bias, the workers were not notified in advance of the interviews. This ensured that workers did not have time to replace their hard hats or "study up" on maintenance requirements.

In Durham, random workers entering the site on the morning of the survey were asked a series of questions. English speaking workers' responses were recorded on a check sheet. If the worker's primary language was Spanish, s/he was given a paper copy of the survey questions in Spanish and asked to indicate his/her answers. Each worker's hard hat was also examined to determine the manufacturer and the date of manufacture. Respondents' names were not captured, nor were company names. No photos were taken. A total of 21 workers were interviewed at the Durham project. At the RTP project, six workers were interviewed on their way to lunch. (Due to the smaller number of overall workers on this site, six actually represented approximately 20% of the total).

The same process was followed at a project in Charlotte with a total of four workers being interviewed as they entered the jobsite one morning. (Again due to the smaller number of overall workers on site that day, this does represent approximately 20% of the total). In Harrisburg, ten workers were interviewed also at the beginning of the work day. The sample size (41 workers) is considered properly representative as the key indicators (percentage of outdated hard hats and outdated suspensions) were generally the same from site to site. Additional data gathering would not likely change the percentages by more than one or two points. The inspection of each worker's hard hat included capturing only objective data. No subjective assessments were made regarding the condition of the hat, such as too many stickers, too scarred, etc. The conditions to which the hat had been exposed (e.g. harsh chemicals, exceptions UV exposure, etc.) over its life were not assessed.

Results

Thirty eight online surveys were completed representing a 36% return rate. The sample size was determined to be adequate, as the key indicators (percentage of companies that included maintenance in their training and percentage of companies with replacement programs) stayed generally the same from the first assessment (done at eleven responses) to the midpoint assessment (done at 26 responses) to the final assessment. Analysis of the results was performed using Qualtrics online tools and is discussed below.

The results of the company survey demonstrated that although *the hard hat is a company's most visible commitment to safety* (Smith, 1994, Pg 2) companies are not as committed to the maintenance of those hard hats as they should be. This is borne out by the answers to questions 6 through 9 and is discussed below. Regarding the demographic questions, respondents represented a good mix of company sizes with most being in the $5 million to $100 million range and most having over 100 employees in the field. Although a majority of the responses were from General Contractors, subcontractors were also represented. All responding companies claim to have written safety policies

and to provide their workers with safety training. However, only 76% of companies include hard hat maintenance in that training. Worker interviews show this percentage about 12% lower. Most significant is the admission that only 37% of companies have programs to actively replace their workers' hard hats. This is further evidenced by the onsite inspections that found almost 30% of workers' hard hats to be over five years old and over 65% of suspensions to be over a year old. When asked how often their workers' hard hat shells are replaced even if undamaged, responding companies answers ranged from "never" to "rarely" to "annually." Of the 37 written responses received, only 20 supplied the correct answer of five years or more frequently. When asked how often suspension systems are replaced, responses were again wide-ranging from "annually" to "never" to "unknown." For this question, only eight of 37 responded correctly.

Cross tabular analysis reveals that the likelihood of a company including hard hat maintenance in their safety training program is directly proportional to the size of the company. Fifty percent of very small companies (by revenue) included hard hat maintenance, while 66% of small companies, 83% of medium sized companies, and 90% of large companies did so. The same relationship holds true using the number of workers in the field to gauge company size, although the percentages are not as linear (66%, 69%, 66% and 88%). Additional analysis reveals that larger companies are more likely to have programs to replace their workers' hard hats upon expiry. Once again the relationship is strong with 0% of very small companies (based on revenue) having replacement programs, while 33% of small companies, 33% of medium companies, and 70% of large companies having programs. A similar pattern exists using the companies' number of workers in the field.

Since all respondents reported to have written safety policies, no correlation could be derived between a company having a policy and including hard hat maintenance in their safety training nor having a program in place to replace outdated hard hats. One additional cross tabular analysis was conducted which revealed that companies that include hard hat maintenance in their safety training are much more likely to have programs in place to replace their workers' hard hats. The results of the worker interviews indicate that the training companies do provide regarding hard hat maintenance is not effective or is ignored in many cases. Workers are indeed risking injury by not caring for their hard hats properly. As stated by Bacon (2001), *effectiveness of any PPE on the job is limited when the product is not properly worn, maintained, and replaced when needed* (Pg 1). Regarding the safety training they were given by the employer, approximately 37% of all interviewees indicated that they were not trained how to care for their hard hat. Furthermore, 61% of those interviewed did not know the correct replacement time for their hard hat shells and 76% did not know the replacement time for the suspensions. This lack of knowledge is ultimately demonstrated by the fact that approximately 30% of the hard hats inspected on site were past the five year replacement timeframe and over 65% were found to have outdated suspensions. Data was derived by subtracting the date the hard hat was manufactured from the date the inspection was made. No allowance was made for time the hard hat may have been in storage or was being shipped before being put to use. Furthermore, it was assumed the hard hats had not been involved in an accident, dropped or otherwise compromised.
Additional analysis was done to determine if time in the industry or native language had an impact on whether the worker knew the proper replacement timeframes and abided by those guidelines. For reference, the average time in the industry of the entire survey population was 13.8 years and 22% of those surveyed spoke Spanish as their native language. As indicated by the computations in Table 2, neither time in the industry nor language significantly affected whether the worker understood the proper replacement timeframes. All of the stratified calculations are within a tight range of the overall average (13.1 to 16 with the overall average being 13.8). The percentage of Spanish speaking workers is also within a few percentage points of the norm (26% and 28% versus the overall average of 22%).

Table 2: Worker Time in the Industry and Language as it relates to Replacement Knowledge

	Time in the Industry		Language	
	Incorrect	Correct	English	Spanish
Shell	13.7 yrs	14.0 yrs	72%	28%
Suspension	13.1 yrs	16.0 yrs	74%	26%

However, time in the industry does seem to affect whether the worker was wearing outdated equipment (Table 3). For both shells and suspensions workers with more experience in the industry were more likely to have hard hats and suspensions that were past their replacement date.

Table 3: Worker Time in the Industry as it relates to Outdated Hard Hats

	Outdated	Okay
Shell	20.5 yrs	13.3 yrs
Suspension	19.8 yrs	8.9 yrs

Overall, the worst offenders were English speaking workers who had been in the business for quite some time. This fact helps focus the discussion and recommendations that appear next.

Discussion

The data collected clearly shows that the NC commercial construction industry, including companies and workers, is not adhering to manufacturers' recommendations regarding hard hat replacement. This failure could result in unnecessary injuries should the hard hat fail to protect the worker as designed. An older shell, being more brittle and less pliable than a new hard hat, could allow items such as a dropped screwdriver, plumb bob, or material such as all-thread or rebar to penetrate the shell and pierce the worker's skull. Even with something as simple as a worker standing up and striking his/her head against a beam, the hard hat could shatter and expose the worker's head. A hard hat with a frayed or stretched suspension if struck could cause the shell to impact the worker's head instead of acting as a shock absorber. The force of the blow transferred to the worker's head could cause serious injury.

Workers do indeed grow attached to their hard hats whether it is the first one the worker owned, is one from a very successful project, or is one that is particularly comfortable or personalized. In light of the data indicating that workers with longer careers are more prone to have outdated hard hats, this emotional attachment to an older hat is quite likely. The less customized the hat is, the less likely a worker is to become attached to it.

Of course, lack of awareness or training is also a culprit in the increased danger to workers. *When asked why some people are reluctant to turn in their old hard hats for new ones, Byrnes offered several theories. The primary reason is that hard hats look so basic, solid, and sturdy that they don't seem like a piece of equipment which needs regular maintenance and replacement. But, as Byrnes pointed out, hard hats are personal protective equipment and are often the only things standing between their wearers and fatal injury* (Smith, 1994, Pg 4). This is especially true for suspensions and is borne out by the data collected. It is a situation in which both the worker and the company are at fault and which can be mitigated using the strategies discussed in the next section. In addition to the incomplete training provided by construction companies, few had programs in place to replace their workers' hard hats.

Conclusion

At the most fundamental and important level, hard hat manufacturers need to do a better job of communicating the limited useful lifespan of their products. These suggestions could not only prevent injuries, they could enhance the manufacturer's reputations and increase sales. First, instructions should be clearer and more prominently presented. Simpler, less legalistic, more user-centric, language could make the importance of replacement more compelling. Second, follow up programs should be considered to remind workers of impending replacement dates. This could be achieved via a simple registration program (like those used for most appliances) in which the owner of the hard hat registers his/her hard hat online then receives automated reminders each year.

When providing the equipment to their workers, companies must provide the hats in the packaging with all of the manufacturer's instructions. No one but the wearer should unwrap and assemble the hat. The person handing out the hard hats should also point out the instructions on the wrapping and allow time for the worker to read them and ask any questions. Second, companies must conduct training that includes hard hat maintenance. This could include simply having the instructor read the manufacturer's instructions or something more memorable like showing YouTube videos demonstrating the impact of strikes using "melon tests." In addition, remedial or reminder training must also be instituted since the data indicated that workers with longer careers are less prone to replace their equipment. This could be as simple as asking everyone to check their hats in a daily huddle or toolbox talk. Lastly, companies should consider adopting wholesale programs in which all workers' hard hats (and suspensions)

are replaced at one time. Such a program might cost more and result in some equipment being replaced before it's absolute due date, but it would make bookkeeping much simpler and would ensure everyone in the company had up to date equipment. Workers joining the company mid-cycle would receive a new hard hat upon employment and simply join in the current replacement cycle. Although some waste might be encountered, the cost of a few hard hats is minor in comparison to an injury.

The issue of hard hat maintenance cannot be taken lightly. The industry's view of hard hats must shift from simple, almost invisible, caps to the major life-saving device they are. Manufacturers, companies, workers and academia (through additional research) must work together to make it a reality.

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