Looking At The Past

1919
Bullard for mining and then Navy ship building. Made from boiled canvas, black paint and glue

1930’s
Hard hats evolved and were made from metals

1940’s
MSA Skullguard fiberglass
1961
New Helmets Introduced

In 1961, the Topgard® Helmet was introduced, which was the first polycarbonate hardhat. Polycarbonate is an extremely durable plastic that is very difficult to crack or break. A year later in 1962, the V-Gard® Helmet launched. Today, both helmets are part of the family of “best-selling helmets.”
OSHA Requirement

In Short: Provide ANSI Z89.1 OR Prove Equivalent

Employees 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.

Criteria for head protection

The employer must provide each employee with head protection that meets the specifications contained in any of the following consensus standards:


The employer must ensure that the head protection provided for each employee exposed to high-voltage electric shock and burns also meets the specifications contained in Section 9.7 ("Electrical Insulation") of any of the consensus standards identified in paragraph (b)(1) of this section.

OSHA will deem any head protection device that the employer demonstrates is at least as effective as a head protection device constructed in accordance with one of the consensus standards identified in paragraph (b)(1) of this section to be in compliance with the requirements of this section.

[77 FR 37500, June 22, 2012; 77 FR 42988, July 23, 2012]
Weaknesses in the U.S. Standards, Regulations, and User Understanding

- **ANSI Z89.1:**
  - Type I hard-hats are only designed for impacts to the crown of the helmet
  - Type II hard-hats offer more protection, but still about an object impacting the helmet, not a fall.
  - Retention systems such as chin straps are completely optional

- **OSHA:**
  - Only addresses minimum standards:
  - Leaves hazard assessment and additional protection measures up to the employer.

- **The User:**
  - Doesn’t have an awareness of the different types of helmets or technologies.
  - Assumes that OSHA and the standards have accounted for the relevant hazards.
  - Type I hard-hats become the de-facto helmet of the industry.
Relevant International Standards

- **European Standard(s)**
  - EN 12492 – Helmets for Mountaineers
  - EN 397 – Specification for Industrial Safety Helmets (ANSI Type 1)
  - EN 14052 – High Performance Industrial Helmets (ANSI Type 2)
# Comparison of All Standards

<table>
<thead>
<tr>
<th>Tested For</th>
<th>ANSI Type 1 (OSHA Min)</th>
<th>ANSI Type 2</th>
<th>EN 397 Industrial Helmet</th>
<th>EN 14052 HP Industrial Helmet</th>
<th>EN12492 Mountaineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Impact</td>
<td>Yes</td>
<td>Yes (Same as Type 1)</td>
<td>Yes</td>
<td>Yes (2x ANSI)</td>
<td>Yes</td>
</tr>
<tr>
<td>Lateral Impact</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Top Penetration</td>
<td>Yes (Conical)</td>
<td>Yes (Same as Type 1)</td>
<td>Yes (Conical)</td>
<td>Yes (Flat Blade)</td>
<td>Yes (Conical)</td>
</tr>
<tr>
<td>Lateral Penetration</td>
<td>No</td>
<td>Yes (Conical)</td>
<td>No</td>
<td>Yes (Flat Blade)</td>
<td>Yes (Conical)</td>
</tr>
</tbody>
</table>

Bold indicates more stringent requirement
Isn’t There Something Better?
Innovation In Fall Protection
First Chance

- August 2012 – City Center DC
- Employee fell 4 feet while dismantling a 2 tier scaffold
- Hard hat fell off
- Induced coma for 3 nights
- No return
- Direct cost of $367,133
From 2003 to 2010, 2,210 fatal TBIs occurred in construction at a rate of 2.6 per 100,000 FTE workers.

**NIOSH: Construction workers at high risk for traumatic brain injuries**

March 29, 2016

Morgantown, WV – Construction workers sustain more traumatic brain injuries than employees at any other type of workplace in the United States, according to a recent report from NIOSH.

Safety interventions must be emphasized in the construction industry, in which more than 2,200 workers died of a traumatic brain injury from 2003 to 2010, researchers said.

Traumatic brain injuries represented one-quarter of all construction fatalities during the eight-year study period, according to the report. More than half of fatal work-related traumatic injuries were a result of falls – particularly from roofs, ladders and scaffolds. Workers 65 and older were nearly 4 times more likely to sustain a fatal traumatic brain injury than workers 25 to 34 years old. Meanwhile, workers at organizations with fewer than 20 employees were more than 2.5 times more likely to die from a traumatic brain injury than those who worked for organizations with more than 100 employees.

Srinivas Konda addressed the findings in a March 21 NIOSH blog post. Konda is an associate service fellow in the NIOSH Division of Safety Research.

Srinivas Konda, MPH,* Hope M. Tiesman, PhD, and Audrey A. Reichard, MPH

Background  Research on fatal work-related traumatic brain injuries (TBIs) is limited. This study describes fatal TBIs in the US construction industry.

Methods  Fatal TBIs were extracted from the Bureau of Labor Statistics Census of Fatal Occupational Injuries.

Results  From 2003 to 2010, 2,210 fatal TBIs occurred in construction at a rate of 2.6 per 100,000 full-time equivalent (FTE) workers. Workers aged 65 years and older had the highest fatal TBI rates among all workers (7.9 per 100,000 FTE workers). Falls were the most frequent injury event (n = 1,269, 57%). Structural iron and steel workers and roofers had the highest fatal TBI rate per 100,000 FTE workers (13.7 and 11.2, respectively). Fall-related TBIs were the leading cause of death in these occupations.

Conclusions  A large percentage of TBIs in the construction industry were due to falls. Emphasis on safety interventions is needed to reduce these fall-related TBIs, especially among vulnerable workers. Am. J. Ind. Med. 59:212–220, 2016. Published 2016. This article is a U.S. Government work and is in the public domain in the USA.
Breakdown Of The NIOSH Study

- 388 (24%) fell from roofs
- 301 (24%) fell from ladders
- 212 (17%) fell from scaffolds/staging
- 19 employees fell and dies from the same walking/working surface

<table>
<thead>
<tr>
<th>Falls</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall to lower level</td>
<td>1,221 (96)</td>
</tr>
<tr>
<td>Fall to lower level, unspecified</td>
<td>28 (2)</td>
</tr>
<tr>
<td>Fall to down stairs or steps</td>
<td>14 (1)</td>
</tr>
<tr>
<td>Fall from floor, dock, or ground level</td>
<td>73 (6)</td>
</tr>
<tr>
<td>Fall from ladder</td>
<td>301 (24)</td>
</tr>
<tr>
<td>Fall from roof</td>
<td>388 (31)</td>
</tr>
<tr>
<td>Fall from scaffold, staging</td>
<td>212 (17)</td>
</tr>
<tr>
<td>Fall from building girders or other structural steel</td>
<td>50 (4)</td>
</tr>
<tr>
<td>Fall from nonmoving vehicle</td>
<td>66 (5)</td>
</tr>
<tr>
<td>Fall to lower level, not elsewhere classified (n.e.c)</td>
<td>89 (7)</td>
</tr>
<tr>
<td>Fall on same level</td>
<td>25 (2)</td>
</tr>
<tr>
<td>Fall to floor, walkway, or other surface</td>
<td>19 (2)</td>
</tr>
<tr>
<td>All other(^a)</td>
<td>6</td>
</tr>
<tr>
<td>Other(^b)</td>
<td>23 (2)</td>
</tr>
<tr>
<td>Total</td>
<td>1,269 (100)</td>
</tr>
</tbody>
</table>
Breakdown Of The NIOSH Study

- 366 (16%) Fatalities from contact with objects and equipment. “Falling Objects”
- 463 (21%) Fatalities from transportation incidents
- 1269 (57%) Fatalities from FALLS!
Breakdown Of The NIOSH Study

- 176 falls involving roofers
- 306 falls involving construction laborers
- 92 falls involving First-line Supervisors or managers of constructions trades

### TABLE IV. Number and Rate of Fatal TBIs per 100,000 FTE Workers in the Construction Industry by Select Occupations—US, 2003–2010

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Contact with objects and equipment n (%)</th>
<th>Falls n (%)</th>
<th>Transportation incidents n (%)</th>
<th>Total n (%)</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural iron and steel workers</td>
<td>10 (18)</td>
<td>39 (68)</td>
<td>—</td>
<td>57 (3)</td>
<td>13.7</td>
</tr>
<tr>
<td>Roofers</td>
<td>176 (93)</td>
<td>8 (4)</td>
<td>190 (9)</td>
<td>11.2</td>
<td></td>
</tr>
<tr>
<td>Paving surfacing and tamping equipment operators</td>
<td>—</td>
<td>12 (66)</td>
<td>14 (&lt;1)</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>Electrical power-line installers and repairers</td>
<td>11 (73)</td>
<td>—</td>
<td>15 (&lt;1)</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Construction laborers</td>
<td>143 (26)</td>
<td>306 (55)</td>
<td>559 (25)</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Light/heavy truck drivers</td>
<td>8 (24)</td>
<td>17 (52)</td>
<td>33 (1)</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>Welding, soldering, and brazing workers</td>
<td>—</td>
<td>—</td>
<td>22 (85)</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>Highway maintenance workers</td>
<td>—</td>
<td>26 (1)</td>
<td>73 (3)</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Cementmasons and concrete finishers</td>
<td>7 (35)</td>
<td>8 (40)</td>
<td>20 (1)</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>First-line supervisors/managers of construction trades and extraction workers</td>
<td>155 (15)</td>
<td>209 (20)</td>
<td>1,044 (47)</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>363 (16)</td>
<td>1,269 (57)</td>
<td>2,216 (100)</td>
<td>2.6</td>
<td></td>
</tr>
</tbody>
</table>
Traumatic Brain Injury

- CDC defines TBI as:
  - Blow or jolt to the head or penetrating head injury that disrupts the normal function of the brain
  - Ranges from “mild” i.e., a brief change in mental status or consciousness to “severe” i.e., an extended period of unconsciousness or amnesia after the injury. Potentially fatal.
Traumatic Brain Injury vs “Other Injury”

- “Other Injury” usually limits the affected body part
  - Fractures and lacerations

- TBI can be acute but mostly occurs chronically.

- TBI affects brain function with symptoms such as headaches, memory lost, concentration, loss of balance, depression and seizures.

- Not easily diagnosed

- Prolonged onset of symptoms
Second Opportunity

- 2014 introduction to the “helmet”
  - “You won’t catch me dead wearing that.”
  - “Did you ride you bicycle to work?”
  - “I’ll stick to my hard hat I’ve had for years.”
Third and Final……

- January 2016
- Employee fell from trailer while unloading
- Hard hat fell off an employee struck his head off the pavement
- Transported by ambulance to ER
- Lacerations to head, fracture to the orbit, diagnosed TBI
- Suffered sensitivity to sunlight, headaches and loss of sleep
Wants & Needs

- Decided to move forward with a chin strap policy with Clark Concrete
- Ensure effectiveness without sacrificing comfort
- Current protection has to be met
- We wanted to “Up the Ante”
Expanded Polystyrene (EPS)

- First Law of thermodynamics (Law of Conservation of Energy) states that energy can neither be created nor destroyed; energy can only be transferred or changed from one form to another.

- Energy from impact involving EPS is absorb during the crushing of foam creating heat and limiting energy from reaching the head/brain.
EPS vs 4 Point Suspension
Third Party Testing

- **Force Transmission**
  - Dropping an 8-lb steel ball from height of 5 feet on top of the hard hat/helmet as it sits on a head form. No more then 1,000 lb (4,400 N) of peak force can be transmitted to the head form and no more then 850 lb (4,000 N) of average force can be transmitted.

- **Apex Penetration**
  - Involves dropping a 2.2-lb pointed steel penetrator with a 60 degree angle on top of the hard hat/helmet from a distance of 8 feet. It must not contact the head.

- **Impact Attenuation**
  - Helmet is attached to a head form and dropped onto a steel anvil. Velocity is constant at 3.5 m/s and results have to be less then 150 (g – gravitational constant) An accelerometer is used measure just like measuring a car crash with test dummies. 150-200 g is an acceleration limit during a bicycle crash while wearing a helmet.
Force Transmission
Apex Penetration
Impact Attenuation
June 30th, 2016
April 2017

- Clark Construction distributed over 3,000 helmets coast to coast
- Led the way with head protection
- Distributed 500 helmets to employees during 2018 Safety Week
- Expanding to trade partners, owners and peers
Goals:

For **Structural Technologies** and for our Industry:

- This is about **saving lives**.
- We’re trying to connect all the different pieces of a solution to provide the industry a **much better** solution.
- We want to share our vision, and hope you feel passionate about being part of this.
Our Call to Action
The U.S. Market – Our Take

- U.S. Standards aren’t complete, and OSHA doesn’t require more.
- Therefore, there hasn’t been a strong U.S. market with Manufacturers haven’t been developing great solutions.
- Solutions are imported from Europe because of more complete standards, and suppliers are charging a premium for better protection.
- So companies are forced to deal with high cost, or selectively protecting people.

To save lives, all these factors need to change.
Recommendations from our Research

- **Minimum; Find a helmet that meets:**
  - ANSI Z89.1 Type 1, Class G **AND**
  - EN 12492 Mountaineering

- **Optional: added certifications or options to provide a total solution:**
  - ANSI Z89.1 Type 1 Class C option:
    - Vented option, potentially cooler for work that doesn’t require class G or E.
  - ANSI Z89.1 Class E option (or instead of Class G):
    - Highest electrical rating for certain scopes of work.
  - Also Meets ANSI Z89.1 Type 2:
    - Additional certification for compliance with facility / market / client requirements.
  - Also Meets EN 14052: High performance industrial helmets.
    - Certain impact benefits above and beyond other standards.

**Note:** Certain standards have competing clauses, so it is not possible to hold multiple certifications in all applicable standards. Instead, you have a core certification(s), and prove compliance with key clauses of other standards. For instance Kask Zenith claims they meet “ANSI Z89.1 + CSA Z94.1, EN 12492 Shock Absorbing Capacity (clauses 4.2.1.2; 4.2.1.3; 4.2.1.4)”
Safety Helmet Initiative: What we want to do

1. **Make a significantly lower cost solution available in the U.S. Market.**
   - ANSI Certification
   - Meets performance reqs of EN 12492
   - $25-$30 target

2. **Start saving lives:** Market the solution within the industry and ensure there is supply to all interested parties. Target industry organizations, industrial clients, and major general contractors to create a trickle-down affect in their specialty contractors.

3. **Lobby for Change:** With low cost solutions, we can push for change to Standards and OSHA reqs without negative impact to the industry. Not cost prohibitive and great success from early adopters.

4. **Watch the Market Adapt:** With growing interest and changing reqs, other manufactures will bring solutions to the table. Product innovation and cost reduction will follow.
Lobby for Change- Industry Efforts

Summary of activities:

- Met with national representatives from LIUNA and Ironworkers.
- Onboard, ready to help reach key industry committees.
- Excited about a company with progressive views in this space, focused on worker safety.
- Attended Ironworkers Safety Roundtable in July to continue to spread message to a national audience and identify actual tactics.
- Key tactic identified is changing the ANSI/ASSP A10 Construction and Demolition Operations Standards.
  - OSHA will change with time and demand from the industry.
  - Product standards are driven by manufacturers.
  - The A10 standards are driven by the industry, apply directly to field operations, and can be seen as establishing best practices and awareness with some immediacy, well ahead of any regulatory change.
Safety Helmet Initiative: Our Efforts So Far

- In parallel to exploring major manufacturers, we looked at alternate sources.

- Research and found an OEM / ODM supplier with an existing Mountaineering helmet.
  - Similar form and function to existing helmet manufacturers
  - Existing EN12492 Certification
  - Face Shield, Visor, hearing protection and other accessories
  - Vented, potential Class C Solution.
  - Cost within range
Key Things We Learned- History and Focus

- Technology / R&D focused at their core with 25 years helmet design experience.
- Sales Mix:
  - 60% ODM – Concept to final product – Specialty designed product.
  - 40% OEM – Direct sales of a helmets for bike and ski.
  - Prefer growth of ODM – their ability to create and manufacture unique solutions is their differentiator.
  - Focus on middle and upper segments of the market. Not interested in competing in the low cost, low quality, commodity helmet production.
Key things we learned - Quality

- Every process had procedure with the equipment and the worker.

- Every model had unique specs and instructions that followed it through the manufacturing process.

- Didn’t observe any worker that didn’t have (what seemed like) the appropriate information to complete their step in the process per spec.

- QC is inherent in what they do, dedicated staff at the end of every process confirming quality. None-the-less, open to any additive qc we might desire. In house or thirds part testing, random sampling, etc.
Testing Facility
Design
Workshopping our Helmet
Helmet Testing

Top Impact Test

Electrical Resistivity Test

Front Attenuation Test
Helmet Development - Our Testing

- ANSI Type 1 Results

**V1 Helmet – Aug 2018 Testing**
Existing EN12492 Certification
Baseline Performance against ANSI

Max Allowable Transmitted Force (N): 15% Reduction of Transmitted Force
Allowable AVG Transmitted Force (N): 27% Reduction of Transmitted Force

**V2 Helmet – Jan 2019 Testing**
Hot: 15% Reduction of Transmitted Force
Cold: 27% Reduction of Transmitted Force
Overall: 22% Reduction of Transmitted Force
Safety Helmet Design Initiative: Our Efforts So Far

- Validated EN certification

- Conducted ANSI Type 1 and 2 testing, some successes but ultimately failure of both.

- Several months of iteration, and we’re at a new version with successful in-house testing by Manufacturer. Biggest changes are in foam density.

- Additional units are in production.
Helmet Samples – Assessing the most cost effective solution
New Helmet Temperature Evaluation

8/8/2019
Objective

- To evaluate the internal air temperature for new safety helmets when exposed to a sunny summer day. Evaluation criteria includes: helmet color, helmet air vents, and internal foam liner.
Test Samples

Vented

No Vent

Original

With Foam Liner

Foam Liner Removed
Test Matrix

- 7 total helmets evaluated

<table>
<thead>
<tr>
<th>Mfg.</th>
<th>Color</th>
<th>Foam</th>
<th>Vent</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M</td>
<td>Blue</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3M</td>
<td>Blue</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3M</td>
<td>Blue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3M</td>
<td>White</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3M</td>
<td>White</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Fibre Metal</td>
<td>ST Blue</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Test Setup

- Test performed from 9:41am until 4:05pm
- Helmets under evaluation were placed on foam heads
- Temperature readings:
  - Recorded every 1 minute using data acquisition system
  - Type K thermocouples used
  - Placed in the air void between helmet and head
    - In the air void between helmet and foam head
    - Between strap webbing and foam head
Test Conditions

- Mostly sunny day
- Max temperature = 92°F
- Average temperature = 88°F
Test Results

No Vent Helmets
Conclusions

Foam liners are effective
- Helmets with a foam liner have a 8-12% lower inside air temp.
- 7-8°F difference for blue
- 7-8°F difference for white

Air vents are slightly effective
- Helmets with an air vent have a 2-3% lower inside air temp.
- 1-2°F difference for blue helmets
- 2-3°F difference for white helmets

White colored helmets are cooler than blue
- White colored have a 3% lower inside air temp. (both with foam liner)
- 3°F difference for white helmets
New Technology
MIPS Technology

- **Multi-Directional Impact Protection System**
  - Reduces rotational forces caused by angled impacts to the head.
  - A helmet’s shell and liner are separated by a low friction layer which allows the helmet to slide, noticeably reducing trauma to the brain in the case of oblique impacts.
  - MIPS layer is located between the liner and the user’s head.
MIPS Technology
Wavecel Technology

- WaveCel is a collapsible cellular structure that lines the inside of a helmet.
- It works like a crumple zone that absorbs the force of an impact before it reaches your head.
Wavecel Technology

EPS FOAM  WAVECEL
Wavecel Technology
Wavecel Technology
Football Helmet Technology

- Deformable shell
- Columns absorb energy and take rotational forces
- The helmet features a soft outer shell and an underlying layer of columns designed to mitigate collisions from multiple directions.
Football Helmet Technology

- Deformable shell
- Columns absorb energy and take rotational forces
Hard Hats to Helmets: We Are not Alone
Industry Leadership – Design Development

- Construction Site Observations
- Construction Interviews
- Comparative Study
- Biomimicry Studies
- Ideation
- Modeling Prototypes
- Final Designs

CLAYCO
THE ART & SCIENCE OF BUILDING
Construction Site Observations

While interacting with Clayco employees and experiencing a large-scale construction site, we gained many insights.

Construction Interviews

Through interviews we are able to learn more about workers' personal opinions, thoughts and questions about their current hard hats and the future design of them.

What are your *immediate feelings* when you think about wearing a hard hat?

- **Too Heavy**: 8%
- **Overheated**: 24%
- **Uncomfortable**: 25%
- **Safety**: 43%

Comparative Study

To understand the existing market for safety helmets, we conducted a comparative study. This allowed us to understand the key features between the helmets being studied which aided in our understanding of creator preferred features to eliminate pain points.

Biomimicry Studies

The students conducted two rounds of revised ideation sketches. From these sketches, they formulated a list of user needs and possible solutions to their problems.
Modeling Prototypes

Feedback from the Clayco team lead SCADpro to reiterate the design process for specific features and combine favored concepts to produce the final three designs. They then began creating their designs in a 3D space so they could truly evaluate its shape and form and how it looks in reality.
Hard Hats to Helmets: What we want to do

▪ Our goal is to dramatically reduce the frequency and severity of Traumatic Brain Injuries in the U.S. Construction industry by:

  ▪ Lobbying for change in the standards and regulations.
    ▪ ANSI + EN12492

  ▪ Partnering with others to drive the awareness and adoption of superior solutions.

  ▪ Making low cost solutions readily available to the entire market.
    ▪ Direct relationships with manufacturers.
    ▪ Market adaptation from growing interest and changing reqs., Other manufactures will bring solutions to the table. Product innovation and cost reduction will follow.
Return On Investment