Roadway Incident Operations: What Is the Right Helmet for the Job?

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By Brady Robinette

The impetus for this article was the deaths and injuries of members of my department while working an emergency on a roadway last January and the questions that have haunted me ever since: "If they were wearing helmets constructed according to standards designed to protect their heads against the impacts they experienced, would the results have been different? Would the head injuries have been less serious?"

Struck-by injuries and fatalities among our nation's emergency responders at roadway incidents have become familiar news stories. In the first seven months of 2020, 30 roadway responders were struck and killed by vehicles while assisting the public.[1]

NFPA 1901 and Fire Helmets

National Fire Protection Association (NFPA) 1901, *Standard for Automotive Fire Apparatus* (2016 ed.), section 14.1.7.4 states: "…. Fire helmets shall not be worn by persons riding in enclosed riding and crew areas. Fire helmets are not designed for crash protection and they will interfere with the protection provided by head rests …."

"Not designed for crash protection" is a strong statement. Although the NFPA is specifically talking about the helmet interfering with head rests (possibly because of the large protruding brim), it appears that the NFPA is also recognizing that structural fire helmets are not rated for "crash protection" in general.

Typically, the types of head impacts at roadway incidents are vastly different from those that occur in structural firefighting. Structural fire helmets are designed primarily for impact protection on the top of the head. At a roadway incident, impacts more likely may be on the sides of the head from a vehicle, flying debris, or the firefighter's being thrown to the ground or into another immovable object.

Limitations of a Fire Helmet at Roadway Incidents

On January 11, 2020, in Lubbock, Texas, a driver from the opposing lane of travel crossed the median while emergency crews were working the scene of an accident. Firefighter Lieutenant Eric Hill and Police Officer Nicholas Reyna were killed. Firefighter/Paramedic Matthew Dawson is still recovering from injuries he sustained at this crash. He suffered many broken bones across his legs, arms, and torso; a cracked skull along with multiple orbital fractures; and a traumatic brain injury (TBI). Months after the crash, Dawson is still at a rehabilitation facility fighting his way through recovering from the horrendous injuries to his body and—perhaps the greater challenge—recovery from the TBI. This senseless scene of destruction forever changed the lives of so many. This crash is still under investigation; therefore, the specific details of the crash have not been released.

Hill was following department standard operating procedures on that fateful day. From all accounts, he handled the scene the same way as any other officer in our department would have. In the wake of this crash, many changes for the future have been discussed and implemented.

Hill and Dawson were wearing their structural fire helmets that day, but the impact of 6,500 pounds of moving metal displaced their helmets completely off their heads. The lingering question is, what would Dawson's injuries have been if he had been wearing a helmet specifically designed and lab tested for the types of forces likely encountered during roadway operations? No one knows for sure, but logic would lead one to reason that his head injuries would have been less severe. Might he have suffered a severe concussion instead of a TBI? Maybe.

Hill's autopsy report cited significant injuries to the head and face. The injuries included lacerations and abrasions to the scalp, a jaw fracture, and multiple skull fractures. Although improved head protection likely would not have changed the outcome, the autopsy findings show just how dangerous and frequent head injuries are at struck-by incidents. Not all struck-by incidents will be survivable regardless of the level of protection worn, but this should not stop us from improving our personal protective equipment (PPE) to give us the best chance of survival.

New Tests and Standards Needed

Structural fire helmets protect against conditions at a structure fire. New tests and standards directed at providing better protection at roadway incidents need to be established.

Working roadway incidents is extremely dangerous. "D" drivers (e.g., drunk, drugged, drowsy, disgruntled, disrespectful, distracted, and dangerous) are anything but predictable. We can shut down the entire roadway, but what about the opposing lane? An apparatus can be placed in the opposing lane as a block, but it's a lot harder to find a position to ensure that a "D" driver can't find a way in. Getting off/on the apparatus when retrieving tools places firefighters in danger from being struck or having the apparatus pushed into them if the apparatus is struck. Geographically dispersed wreck scenes present issues for blocking apparatus, as do incidents just off the roadway where apparatus may not be able to take the blocking position because of uneven or soft surfaces. It is virtually impossible to ensure our safety at roadway incidents. Many departments respond to roadway incidents more often than any other type of working fire incident.

"Struck-by-vehicle line-of-duty deaths, injuries, and emergency vehicle damage at roadway incidents continue to be problematic for emergency services, and, in fact, the number of incidents is on the rise," according to Jack Sullivan, director of training at the Emergency Responder Safety Institute (ERSI). For years, ERSI has recommended the use of fire helmets and high-visibility PPE for personnel working roadway incident scenes. The helmet recommendation is based on anecdotal information from firefighters directly involved in struck-by-vehicle incidents. Proposed improvements include (1) making the responders more conspicuous by adding fluorescent and reflective markings on their helmets and (2) providing additional physical head protection.

My New Mission

The roadway accident in Lubbock in January 2020 prodded me down the path of researching for a protective helmet for roadway work. I began by showing photos of various types of helmets to seasoned firefighters and asking them, "If you were going to get struck by a vehicle on a roadway, which helmet would you rather be wearing?" The most popular choices were the off-road dirt bike and the car racing helmets. I then asked which helmet would be the worst possible helmet for this scenario. The unanimous answer was the structural firefighting helmet. Right there and then, I knew I had a new mission in life. It is a mission I would like to continue by working with fire departments, research institutes, laboratories, helmet manufacturers, and standards bodies to develop better head protection for emergency responders at roadway incidents.

The research performed for this article was on a very limited budget. The impact of COVID-19 has frozen our budget. Many standards relevant to helmets are viewable only if you purchase the standard; therefore, I could not review as many helmet standards as I would have liked. The helmets tested in the roll-off test were helmets I owned, borrowed, or obtained from one manufacturer. The roll-off test apparatus was built mainly out of scrap metal and economically available parts.

Structural Fire Helmet Features and Protection

Protruding Brim. A protruding brim is a prominent feature on most fire service helmets. The brim is designed to prevent water, debris, and hot embers from going down the collar of the jacket. The brim also adds styling. Depending on the manufacturer and model of the helmet, the brim can protrude 1½ inches on the front, 1 inch on the sides, and up to 3½ inches on the back. When struck up against an object, the large protruding brim can amplify forces.

A class 1 lever (Figure 1) represents the same concept. The input force in this example would be the impact energy (a moving vehicle). Distance would be from the center of gravity of the helmet to the tip of the brim. The longer the brim, the more output force that could act on the wearer's head and neck. The protruding brim striking an object could also cause forces that would displace or completely remove the helmet from the wearer's head.

Figure 1. Class 1 Lever Depicting Output Force on Wearer's Head and Neck

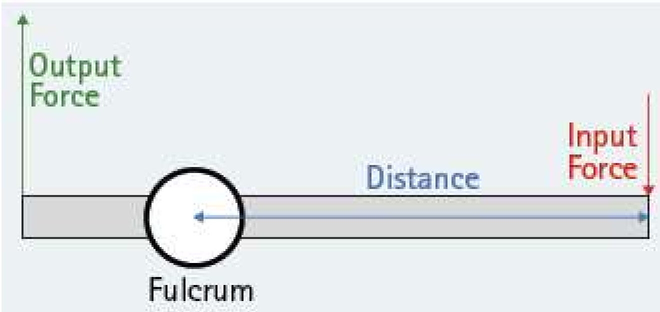


Illustration provided by author.

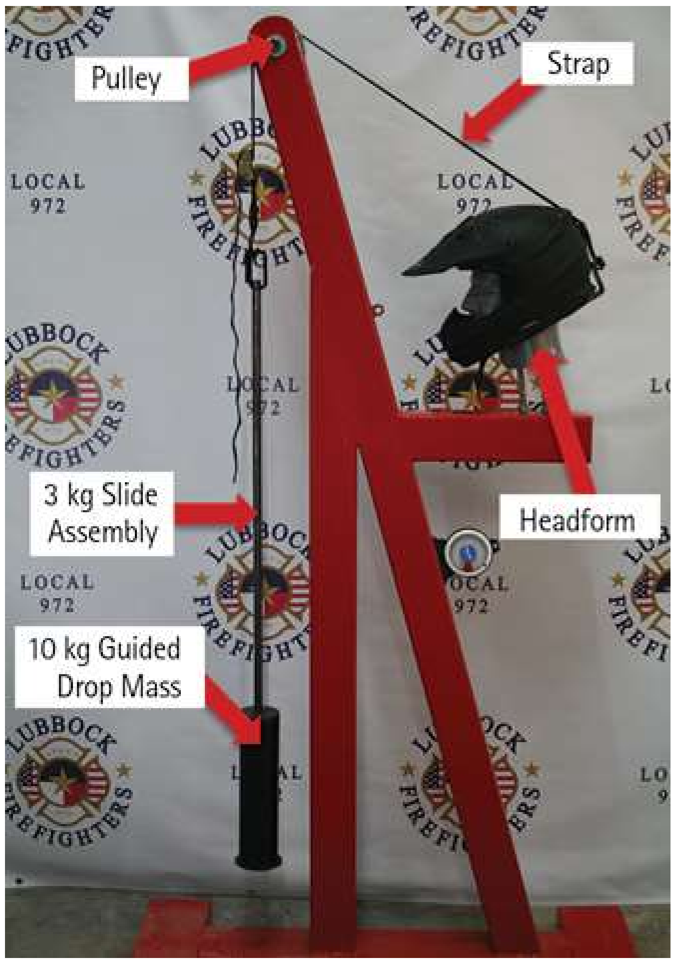
The protruding brim could cause unexpected injuries to the head and neck as the brim deflects off an object. This deflecting action could increase rotational forces. "A rotational motion is going to cause strain or stretching of the brain tissue. That stretching is a dominate factor in producing injuries like concussions or more severe diffuse brain injuries," Steve Rowson, Ph.D., an associate professor in the Department of Biomedical Engineering and Mechanics at Virginia Tech and director of Virginia Tech's Helmet Lab, explained in a personal communication. The ideal "crash-rated" helmet would be a smooth spherical surface that allows the helmet to slide along an object instead of digging in and transferring energy to the wearer's head and neck.

Another consideration here is that when firefighters need to enter the interior of a vehicle to provide patient care, they typically remove the fire helmet and place it on top of the vehicle because its size makes it difficult for firefighters to maneuver and perform their duties in tight quarters. If the helmet is not on the head, it cannot provide any protection!

Positional Stability. Structural fire helmets inherently are heavy and sit high on the wearer's head. The resulting high center of gravity can cause the helmet to fall off or dislodge. A chinstrap can help hold the helmet on the wearer's head, but even if the chinstrap is in place and securely tightened, that doesn't ensure that the helmet will stay on the wearer's head. NFPA 1971, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting* (2018 ed.), does not have criteria for testing roll-off (a.k.a., positional stability) to determine to what degree the helmet will dislodge when a force is applied to its edge.

The SNELL Foundation®[2] and some other helmet standards specify criteria for roll-off tests with the helmet attached to a head form that is typically at a 45° angle down from horizontal. ECE 22.05[3] has a similar test, referred to as a retention (detaching) test, which is performed with the head form upright in the vertical position. To pass the test, the helmet must not dislodge more than 30°.

Since structural fire helmets don't tend to stay in place as well when upside down, we developed a roll-off test apparatus as close as possible to ECE 22.05[3] specifications in a nonscientific setting (photo 1). ECE 22.05 specifies a 20-inch (500-mm) drop of a 22-pound (10 kg) guided mass. The slide assembly that guides the drop weight weighs seven pounds (3 kg). Other standards use the same test apparatus with the same drop weight and slide weight, but they specify a lower drop height. Tests used for this article used a drop height of seven inches (175 mm). The slide assembly is attached to the back of the helmet by a strap. The weight of the slide assembly and drop weight act to pull the helmet up and forward at approximately a 45° angle.



(1) The roll-off test apparatus based on ECE 22.05 specifications. (*Photos courtesy of author.)*

The head form used for these tests was not the head form specified in roll-off tests by standards; those forms can cost up to $1,000 or more. The chinstrap and headband adjustment were secured to normal-wear tightness. The tests performed with this apparatus are estimations of the positional stability of different helmets as opposed to a definitive result as per a standard. Our tests included multiple structural fire helmets, a hard hat, a snow sports helmet, a search and rescue helmet, and an off-road dirt bike helmet (Figure 2).

Figure 2. Helmets Before and After the Roll-Off Tests Were Performed

(Left) Structural fire helmet #1 came off the head form and wedged up against the test apparatus. This prevented it from falling to the floor. (Right) The shell and headband assembly separated from structural fire helmet #2 and pulled it to the point seen in the after picture.

(Left) Structural fire helmet #3 came completely off the head form. (Right) Structural fire helmet #4 (a European-style helmet) stayed on the head form but rotated forward to a degree that I would consider a failure.

(Left) Hard hat #1 came completely off the head form. (Right) Snow sports helmet #1 performed well, rotating only a few degrees forward.

(Left) Search and rescue helmet #1 performed well, rotating only a few degrees forward. (Right) Off-road dirt bike helmet #1 performed satisfactorily, rotating forward slightly more than the previous two helmets.

Most structural fire helmets have the chinstrap attached at two points. Helmets with a four-point chinstrap perform better in roll-off tests. The additional two points of attachment toward the rear of the helmet help hold the helmet on the wearer's head when rotated forward.

You can perform a simple roll-off test with any helmet. Place the helmet on your head, tighten the chinstrap and headband adjustment system as you normally would, and apply pressure to rotate the helmet forward. Do not let the helmet strike your nose or face. You can apply pressure to rotate the helmet backward.

Webbing Suspension System. A webbing suspension system has been used in fire service helmets for years. It typically consists of a four- or six-point suspension and is typically used where an impact on the top of the head is expected. Structural fire helmets and hard hats are some of the most common helmets with suspension systems.

Lab tests show that suspension systems perform well in top-impact tests but not as well in side impacts as helmets with energy-absorbing material that fits snugly around the wearer’s head[4] (e.g., a motorcycle helmet). Helmets with webbing suspension systems have a headband that encircles the wearer’s head and that can be adjusted. Even when the adjustment is snug, slack and play allow the head to rotate inside the helmet. Typically, in crash-rated helmets, the head fits snugly up against the energy-absorbing systems with as little lateral or vertical movement as reasonable. I do not recommend a webbing suspension system be worn anytime impacts from the sides of the head are likely. Webbing suspension systems should be tested by a laboratory during crash-type scenarios such as being struck by a vehicle or debris from the side to determine their effectiveness.

Area of the Head Protected. Obviously, helmets can protect only the area of the head covered by the helmet. This is the most visible deficiency of traditional structural fire helmets (photo 2). The area outlined in red is physically unprotected by the helmet. Additional rear and side protection is needed to properly protect the entire head. Helmets with chin bars provide additional protection to the chin and face more so than open face helmets.

(2) The area outlined in red is not protected if the crash impact is from the side.

Injuries to the Brain

The primary mechanisms of brain injury that firefighters are at risk for at roadway incidents are direct impact, acceleration/deceleration forces, and penetrating trauma. Direct impact forces are linear (acting in a straight line) or rotational (rotating about an axis) forces or a combination of both. Brain injuries can be broadly categorized as focal or diffuse. Focal injuries consist of contusions (bruises), hematoma (bleeding), or swelling in small specific areas of the brain. Focal and penetrating injuries affect a specific portion of the brain. Diffuse injuries are associated with widespread brain damage. Diffuse injuries can cause widespread swelling, concussions, and diffuse axonal injury (DAI). Axons are the communication pathways in the brain. DAI causes an interruption of electrical transmissions in the brain by means of damaged or sheared axons.[5-8]

Other Industry Standards and Technologies

Rotational energy-absorbing systems are new technologies manufacturers are incorporating into helmets for use in sports, construction, and the military. These new systems allow the head to rotate independently of the exterior helmet shell. This allows mitigation of some of the rotational energy. Rowson says, "In terms of brain injury, rotational forces are of greater concern than linear forces. We have really good ways of managing linear forces right now. A little bit of foam goes a long way in reducing linear forces, but traditionally managing the rotational forces has been very difficult. It is only recently that we are starting to see technologies where people are more effectively managing the rotational forces that stretch the brain tissue."

Initiative #8 of the 16 Firefighter Life Safety Initiatives[9] states: "Use available technology whenever it can produce higher levels of health and safety." Integrating rotational energy-absorbing technologies into roadway helmets would be a good example of meeting this initiative.

One could argue that standards for motorcycle helmets are more closely aligned with protecting against the types of forces a firefighter would experience in a struck-by incident on the roadway than those stipulated in NFPA 1971. According to SNELL M2020[2], four of the most critical elements affecting a helmet's protective properties are impact management, helmet positional stability, retention system strength, and extent of protection.

The structural fire helmet does not provide the positional stability and extent of protection needed in roadway work. The fire helmet fails in impact management because of its propensity to come off the head, the significant area of the head not covered, and the poor performance I anticipate when impact testing against the brim. NFPA 1971 specifies chinstrap strength tests. More testing and evaluation are needed to determine the adequate chinstrap strength for a roadway helmet.

European-Style Structural Helmets

European-style structural helmets are frequently brought up when discussing the need for a better roadway helmet. After evaluating helmets from two manufacturers, I do not believe a European-style helmet would provide the adequate “crash protection” needed at roadway incidents. It would provide better protection than a traditional fire helmet, though. It covers a larger portion of the head and does not have a large protruding brim. One model evaluated limits external protrusions, and both helmets had a four-point chinstrap. However, European structural helmets have a webbing suspension system, which I do not recommend when impacts from the sides of the head are likely. The two helmets had a thin foam layer inside the helmet, which stops well short of covering the area covered by the outer shell; it covers mainly the upper portion of the helmet. The helmets had significant internal protrusions (e.g., brackets and hardware for the shields or lighting equipment), most prevalent on the sides of the helmet, which could be dangerous during impacts to the side of the head.

Recommended Helmets for Roadway Use

My research goal was to develop a list of helmets recommended for roadway work, but no helmet on the market matches all of the criteria important to roadway safety. However, I would recommend full-face off-road dirt bike helmets that contain technologies to mitigate rotational forces. These helmets would provide significant protection. Many are on the market, and I did not evaluate each one, so, I could not narrow the list. Prices range from about $130 to $750. Among the cons are reduced communication, hearing, vision, and ventilation. They come in different sizes and need to be fitted to each wearer. The large visors on these helmets are removable, which would help decrease the size of the helmet.

The other type of helmet I would recommend is a search and rescue (SAR)-style helmet, such as the one used in the roll-off tests. Select one with foam for head protection instead of a webbing suspension system. Although a SAR helmet will not provide the same level and extent of protection as an off-road dirt bike helmet, it will perform better in the areas of communication, hearing, vision, ventilation, and comfort. SAR helmets are typically one size fits all. They generally cost less than $200.

Some SAR helmets have a break-away chinstrap, which is typically used in industrial applications and would NOT be ideal for a roadway helmet. Additionally, some SAR helmets can be used for technical rescue, swiftwater rescue, and vehicle extrication incidents. Both Lubbock Fire Rescue and Wolfforth Fire & EMS have approved a SAR helmet for use on roadway incidents that do not involve a fire incident.

Additional Criteria for Roadway Safety Helmets

As already discussed, crash protection is the priority when designing a roadway helmet for emergency responders. Standards should consider linear and rotational force mitigation, the area of the head covered, roll-off/positional stability, resistance to penetration, maximum protrusion length, retention system strength, and chin bar strength tests, if so equipped.

The helmet should permit communication from crew to crew and from crew to patient and make it possible for responders to hear the surrounding scene sounds to help alert them to possible danger. It should provide built-in or attachable eye protection that meets standards such as ANSI/ISEA Z87.1, *Occupational and Educational Personal Eye and Face Protection Devices*, standards and permit sufficient vision in the vertical and horizontal fields of view.

The helmet should be safe and comfortable. For example, it should provide ventilation for adequate cooling in hot environments and should provide visibility for low-light conditions, perhaps with the use of reflective or fluorescent trim to improve visibility and conspicuity; should have resistance to chemicals and body fluids that may be on the scene and an inner construction that can be cleaned to remove contaminants; and should have a reasonable cost, be durable, and have at least a 10-year service life.

Statistics: The Missing Piece of the Puzzle

Research to prove or disprove the effectiveness of structural fire helmets during a crash-type event does not exist. A helmet testing lab would have to put a structural fire helmet through a battery of tests. Statistics are also lacking relative to properly tracking and analyzing the number of struck-by injuries and near misses for our nation's emergency responders.

The National Institute for Occupational Safety and Health publishes detailed investigation reports on some firefighter fatalities, but they do not include the information necessary for research on helmet effectiveness. The reports do not consistently list whether the firefighter had a helmet on, whether the chinstrap was secured, whether the headband was properly adjusted at the time of impact, whether the helmet remained secured to the head, or the physical condition of the helmet after the incident. The cause of death is typically generically listed as "blunt force trauma." It would be helpful to know if the head was involved in the trauma, along with the specific injuries to the skull and brain.

Additionally, no studies specific to vehicle vs. emergency responder testing could be found, although there is much material on vehicle vs. pedestrian victim testing. Simulation software to virtually test or reconstruct a vehicle vs. pedestrian accident exists. To determine the forces emergency responders are likely to experience in struck-by incidents, existing vehicle vs. pedestrian tests and research will have to be adapted or new tests and research will have to be performed. Crash dummies fitted with accelerometers for both linear and rotational acceleration would be the best way to determine the likely forces responders' heads would experience in a struck-by accident.

What You Can Do

Reach out to whoever will listen to you about helmet safety for firefighters at roadway incidents. Talk to your fellow firefighters. Call or e-mail your helmet manufacturer and state that you want a helmet that provides more protection for roadway incidents. Call or e-mail your local, state, and federal legislators to express your concerns.

It is reasonable to assume that structural fire helmets will provide some degree of protection at roadway incidents, but they must be properly secured. Adjust the chinstrap and headband snugly each time you wear your helmet. Administrators should consider requiring a helmet with properly secured chinstap and headband adjustment tightened on roadway incidents in their standard operating procedures.

If the structural fire helmet is the only helmet you have, wear it at roadway incidents. Don it before exiting the apparatus and do not doff it until you return to the apparatus. NFPA standards do not mention whether a helmet should be worn at roadway incidents. This gives departments the option of picking a helmet they feel will best protect the firefighters' heads at roadway incidents. Review your procedures; local, state, and federal laws; and NFPA standards for any recommendations they may contain.

Review the specifications and standards to which the helmets were certified. Compare prospective helmets against criteria you believe are important for a roadway helmet. Each helmet has pros and cons; carefully weigh them.

Note: The views and opinions expressed in this article are mine and are based on knowledge gained through the research available at the time of publication and my real-world experiences. These views and opinions may or may not align with the departments and organizations with which I am involved.

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BRADY ROBINETTE is a lieutenant with Lubbock (TX) Fire Rescue and a member of the Lubbock Fire Rescue Traffic Safety Committee. He has served for 13 years as a volunteer with Wolfforth Fire & EMS. He has an associate degree in computer science; is an advanced structural firefighter and advanced EMT; and is certified in swiftwater rescue, confined space rescue, and trench rescue.