Introduction

Proper egress system design is important for life safety in buildings. In the event of an emergency evacuation, people inside the building need to be evacuated in an efficient and safe manner. The standards that provide requirements for egress systems (NFPA 101 and the International Building Code (IBC)) are updated on three-year cycles and the requirements in the codes come from lessons learned from previous fires. Typically speaking, when the egress system fails, it is not a matter of something novel occurring. Instead, the requirements of the code were not followed. Designers, code officials, employers, and/or building owners can violate these requirements due to poor understanding of the standards, lack of adherence to the requirements, reconfiguration of the space, security concerns, poor maintenance, or economic concerns. Many fatal emergencies (e.g., the Beverly Hills Supper Club fire) have occurred in buildings where the requirements of the standards were not met.

While this has been an historic problem, it is still relevant in the modern world. Recently, the Oklahoma Fire Marshal addressed the Oklahoma American Institute of Architects, stating that a huge backlog for code reviews is occurring throughout Oklahoma. Similar situations are occurring throughout the United States. This is due not only to budget cuts and frequent changeovers, but also to the fact that code compliance in architects’ plans is lacking. Ideally, architects would know the requirements of the codes and submit compliant drawings. Instead, architects typically rely on Fire Marshals to correct code errors. In some cases, the enforcement and interpretation of the codes is inconsistent, leading to confusion about what actually needs to be included in design. Everyone involved with the design and approval process of egress systems needs to be knowledgeable about the requirements in the standards. Non-code compliance can result in significant economic impact. There are significant delays when the drawings must be submitted multiple times. The changes that are required later in the process typically cost significantly more than changes at the conceptual design phase. In addition, the changes occurring during construction can lead to the loss of floor space that could otherwise have been used for commercial or similar activities. Poor adherence to the requirements of the codes is not beneficial to anyone involved in the process. The best solution is to educate the future architects, other system designers, and code enforcement officials about the code and thus have compliant designs throughout the project.

Student Awareness of Codes and Standards

Our experience with teaching students about the standards is that they have difficulty grasping the importance, basis, and nuance of the requirements. They do not fully grasp the significance of the standards and why adherence is an absolute requirement. Even though the topics are covered in lectures and the students are tested on them, they still do not understand why they have to be used; consequently, they fail to apply them independently when developing designs or reviewing drawings. By being able to see the consequences of failure to adhere to the standards, or to understand how particular emergency events can be avoided or minimized by following the standards, students will be able to apply the standards as intended. The use of three-dimensional models will also enable them to see and better internalize the requirements.

Although there are numerous emergency egress training videos, those videos focus on developing emergency evacuation plans. While understanding emergency evacuation plans is important for the users of the building, it does little to help architects and reviewers understand the requirements for designing a building. Instead, an educational video focusing on emergency egress building design strategies and hazard identification in accordance with the standards was needed. Other videos available on the internet provide sometimes graphic accounts during an emergency event, but they lack objective analysis of why or how that event unfolded.

Development of Video

Oklahoma State University (OSU), through a grant from the National Institute of Standards and Technology (NIST), created a fifty-minute video as a learning resource to be integrated into existing undergraduate courses to educate students about the importance and content of documentary standards related to building egress. A video was selected as the ideal tool to teach about egress system requirements for multiple reasons. First, a video freely available online would enable the students to review it at any time. The classic lecture format of presenting the material limits the ability of students who do not fully understand the concept from being able to review the material outside of class. While these students could ask for clarification either in lecture or in office hours, many students choose to not do so. Second, a video allows the material to be easily shared with others throughout the United States and the world. Anyone who is learning about egress systems can access the video, and professors who may have limited knowledge of the topic can easily present it in class. Third, a video can incorporate images from actual events, computer models, actual people movement, and other visual representations of the concepts that are covered. By including this range of media, the students are better able to visualize and grasp the concepts.

The objective of the video is to help students to identify common errors that are made relating to the documentary standards for egress systems in order to help to ensure that these problems are addressed before an emergency occurs in an existing building and before the plans are submitted for review for a new building.

The video also addresses people’s state of mind in an emergency to show how safe egress design is essential for safety. This is included in the video so that students can comprehend why the requirements are in the standards. The students are far more likely to remember the requirements of the standards if they know why those requirements are there (typically from fatalities during an emergency) rather than simply being presented with a list of requirements to memorize.

While the video is targeted to students in the fields of fire protection, architecture,
and civil engineering, it has the potential to benefit many others. The content is applicable to anyone that applies the requirements of the standards related to egress systems. For example, it can be used to educate property owners and managers about why requirements apply. Similarly, cities could use it to help train new inspectors and plan reviewers.

Goals

The primary goal of the video is to improve a viewer’s understanding of the code and his or her ability to identify code issues in building floor plans. The intention is that this would be achieved by not only demonstrating essential calculations of egress design using visually appealing contemporary buildings with three-dimensional models, but also by incorporating powerful first-hand accounts of emergency experiences. Relevant case studies that directly influenced code standards and changes are explained and diagrammed. The case studies and human perspective stress the importance of the methodical calculations.

Viewers are expected to understand the importance of standards in safe egress design, to be able to perform basic code calculations, to design buildings that are code compliant, and to be able to identify errors in drawings. All of these skills are covered with examples and case studies within the video. In addition, viewers can understand the needs of different occupants. Featuring a variety of community groups (including children, the elderly, and college students) in the videotaping reinforces the varying abilities and experiences of occupants.

Project Outcomes

The video, released with and without captioning on YouTube (non-captioned at https://www.youtube.com/watch?v=9KLr1_CBHio, and open captioned at https://www.youtube.com/watch?v=K9PTRHgxzy2), is easily accessible and has been widely distributed to academic programs throughout the country that teach areas related to the building codes. The video is easily accessible to any student, instructor, or professional. A high-resolution file on a DVD was sent to every accredited school of architecture and fire protection and safety program in the country. Most of the over 2,600 viewers (seventy-two percent) are from the United States, but viewers have been reported from other countries, including Peru, Canada, Guam, and Malaysia.

The fifty-minute video covers basic emergency egress design, and begins with general definitions of occupancy classifications, highlighting important issues to consider for each. It continues with simple calculations of occupant load, as those numbers determine many aspects of egress design. Throughout the video, fundamental definitions are diagrammed and demonstrated verbally, graphically, and in videotaping. Both historical and contemporary case studies are also integrated throughout the video to reinforce egress standards by explaining egress failures, analyzing why they occurred, and sharing accounts of victims’ first-hand experiences. NIST and the National Fire Protection Association (NFPA) provided clips of controlled testing, including the recreation of a nightclub fire in real time as it happened without sprinklers, and then with sprinklers, demonstrating the dramatically different results. A demonstration of more detailed calculations, such as the number of required exits and the width of corridors, doors, and stairs, is enhanced with animated graphics, as are maximum travel distances. These are repeated later in the video at a quicker pace with an elementary school building example.

In the design of egress systems, there are several key concepts to understand and features that need to be applied in order to ensure that the people in the building can safely evacuate. These features can improve daily use of the building, but the failures of the system are not noticed until an emergency occurs. These features are:

- **Occupancy classifications**: definitions and examples are provided. Determining the intended use of a building affects many subsequent aspects of egress design in the standards and is essential for determining the appropriate occupant load.
- **Occupant load**: the maximum number of expected occupants at any given time in a building or room is determined. This number is used to calculate the number of exits and their widths.
- **Exit Access, Exit, and Exit Discharge**: definitions and examples are provided. Exit Access is the area of the egress system that leads from an occupied area to an Exit. An Exit is the safe portion of the egress system that leads to Exit Discharge. Exit Discharge leads to a public way.

- **Adequate exit width**: scenarios demonstrate how decreases in egress width below the levels required in the standards can greatly increase the required safe egress time (RSET).
- **Changes in width**: a decrease in width, even if still above the code minimum, will force people to get cut off and increase RSET. The standards do not allow for it, but it is one that students have trouble understanding.
- **Merging flows**: where two components meet, the egress width has to be sufficient to meet the needs of the combined flow. The methods for accounting for merging flows are different for stairs and other egress components (e.g., corridors and ramps).
- **Door swing**: a door swinging inward can cause people to become trapped as the crowd surges behind them.
- **Main entrance requirements**: scenarios have more people heading towards the main entrance, showing the need for that exit to have sufficient capacity. Because people tend to leave the same way that they entered, the standards require that the main entrance in assembly occupancies have a greater capacity for this reason.
- **Remoteness of exits/exit discharge**: the standards require that exits are located remotely to ensure that a single event does not cause the loss of all safe paths out of the building, but this can be neglected by people not familiar with the standards.
- **Dead-end corridors**: presence of a dead-end corridor can cause people to become confused and/or delay evacuation (potentially leading to fatalities) as they look for an exit or bypass an exit during an emergency.
- **Common path of travel**: having only a single egress path from a given location can be fatal when that path becomes blocked.
- **Maximum travel distance**: the standards place restrictions on how far exits can be from the most remote areas of a room or building in order to make sure that people can safely evacuate before conditions become untenable.
• **Increasing level of safety along an egress route:** it is required that once people are in a safe exit, they must remain in a location of safety until exit discharge. Designers not familiar with this requirement can have egress systems that lead people through spaces that are not allowed.

• **Locked exit doors:** for security reasons, employers can lock doors in violation of the standards to prevent people from stealing, leaving without paying, or taking unauthorized breaks; scenarios show how heading towards a locked door can potentially lead to loss of life.

• **Fire Rating:** materials and assemblies are rated in terms of their relative level of fire-resistive performance. The meaning of these ratings is explained.

• **Sprinklers:** the presence of sprinkler systems can greatly increase the chances of survival in a fire emergency, although they are not necessarily designed to extinguish a fire.

**Case Studies**

Examples of egress system failures are discussed in the format of brief case studies. By visually presenting the consequences of less effective or incorrect design, students, employers, and workers who view the film are able to better personalize why these tragedies are rated in terms of their relative level of fire-resistive performance. The meaning of these ratings is explained.

**Impact**

During early development, a twenty-two-minute draft video was shown to a class of architecture and architectural engineering students in the Comprehensive Design Studio, to a class of fire protection and safety technology students in the Structural Design for Fire and Life Safety course, and to a group of fire protection professionals. The intent of the draft video was to determine what the target audience found to be most helpful and what they did not like about the video. This enabled changes to be made for the final version so that it would best suit the needs of contemporary students learning about building codes.

A questionnaire was distributed to the students asking them about their impressions of the video and what elements they would like to see more of as the video was expanded. Similar results were found for each class.

The architecture students completed a questionnaire regarding its content. Figure 1 shows the form and the results; this input assisted in further development of the video. Overall, they appreciated the video and its direction. Some students noted that to improve the video, they would like to see another modeled building and case studies, but others thought that the Pathfinder (egress) models would be redundant. Ultimately, the more detailed Pathfinder stair diagram was eliminated due to video time constraints. The fire protection students had similar responses. All of the possible expanded content had some students rate at five and others at one; there was nothing that was universally indicated as essential.

<table>
<thead>
<tr>
<th>Students</th>
<th>Architecture</th>
<th>Fire Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Was the information clearly presented?</td>
<td>4.55</td>
<td>4.63</td>
</tr>
<tr>
<td>2 Did the diagrams help to explain the verbal content?</td>
<td>4.63</td>
<td>4.45</td>
</tr>
<tr>
<td>3 Would you review the video on your own?</td>
<td>3.97</td>
<td>3.71</td>
</tr>
<tr>
<td>4 Would this video be helpful to you in understanding egress better?</td>
<td>4.55</td>
<td>4.68</td>
</tr>
<tr>
<td>5 Knowing the content will expand, please rate what you think would be helpful information to include:</td>
<td>----</td>
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</tr>
</tbody>
</table>

Another building example with contemporary design and complicated egress issues

Examples of previous fires and what went wrong

Models using Pathfinder (or similar) showing people moving in an egress situation

More detailed stair diagram explaining the important aspects of egress stair design

Figure 1: Student response of draft video viewing.
In May 2015, the draft video was also shown to a group of three professionals in the fire protection engineering field who were taking a continuing education course at OSU. They were very impressed with the video and their main comment (before being told the purpose of the draft) was that the video needed to be longer. They found all of the content to be helpful and beneficial.

In November 2015, portions of the video were shown at the Oklahoma American Institute of Architects Convention. The title of the presentation was Human Behavior and Case Studies’ Influence on Standards in Egress Design, and Jeanne Homer presented this with Yuen Ho, the Assistant Director of Development Services for the city of Tulsa, Oklahoma. The presentation reintroduced basic concepts about egress from the perspective of human experience and case studies. Over sixty architects were present, and each was given a quiz of twelve questions. 63.5 percent scored a perfect score after viewing the video, 23 percent missed just one, 11.5 percent missed two, and only two percent missed more than that. The content for questions 2, 6, 7, 8, 9, 10, and 11 in particular were covered in the video clip. In the end, the architects responded well to what can normally be considered dry material. Figure 2 shows the quiz with the correct answers and percentage of architects who answered it correctly.

In the Comprehensive Design Studio, the impact of the video on student understanding of egress design issues is clear, as shown in Figure 3. A quiz requiring about forty students to identify ten code violations in floor plans for a two-story theatre has been given each year since 2013. In 2013, the class average was 81, and in 2014 it was 56.9. The poor performance prompted the project of creating the video. In 2015, the year we showed a draft of the video, the class average rose to 89.1. In 2016 and 2017, students viewed the entire completed video, and the average rose again to 91.2 and 91.8, respectively.

A review of the draft video and a final review of the nearly completed video were performed by the Tulsa Development Services code officials, Yuen Ho and Evona Garner. They commented on several items, particularly involving new code material introduced in the adoption of the 2015 International Building Code from the 2012 version. This transition occurred during the creation of the video, so tables and reference numbers needed updating, and a few pieces of information changed (e.g., how to calculate the occupant load of a mercantile space). They corrected other issues with graphic representation or animation. They were a valuable asset to the development of the film.

### Comprehensive Design Code Quiz Results

<table>
<thead>
<tr>
<th>Year</th>
<th>Class Average</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>56.9</td>
<td>Draft video introduced</td>
</tr>
<tr>
<td>2015</td>
<td>89.1</td>
<td>Final video released</td>
</tr>
<tr>
<td>2016</td>
<td>91.2</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>91.8</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Architecture student quiz results.
Lessons learned

The final video turned out very similar to what we had originally envisioned. The draft video and incorporating target audience feedback was essential in the completion of the final video. Showing it to a wider audience helped in determining what features worked and which ones did not. Also, production delays were a problem and more time allocated for that process was needed.

Conclusion

Understanding abstract standards is something that many students struggle with. The difficulty can be compounded if they believe that the responsibility of applying the standard will fall to someone else. However, it is essential that everyone involved in the design and review process know and apply the standard in their daily work. This ensures fewer delays and buildings that are safe. In order to help teach about the requirements for egress systems, we developed an instructional video about basic egress requirements. As a result of using this video as part of instruction, the students are demonstrating a better understanding of the requirements of the standards.

About the Authors

Dr. Bryan Hoskins is an Assistant Professor of Fire Protection & Safety at Oklahoma State University. He earned his BS and MS degrees in Fire Protection Engineering from the University of Maryland, and his PhD degree in Mechanical Engineering from the University of Maryland. Dr. Hoskins is the author of more than two dozen publications related to human behavior during emergencies. He is an active member of the SFPE and NFPA.

Professor Jeanne Horner received her Bachelor of Science from the University of Illinois at Champaign-Urbana and her Master of Architecture at Arizona State University in Tempe. She has been a practicing architect since 1998. In addition to carrying on an active architectural practice, many of Jeanne’s scholarship and creative activities relate to teaching the Comprehensive Design Studio. Topics include collaboration and integration of systems.

SES Directors Elected

There were no nominations from the membership following the publication of the recommended slate of candidates for the available Board positions. Therefore, the following individuals are declared elected to the specified positions.

President
Ed Mikoski (Electronic Components Industry Association)

Vice President
Mili Washington (Institute of Inspection, Cleaning, and Restoration Certification)

Secretary
Gillian Ottley (ULC Standards)

Treasurer
Craig Cerniglia (Comm2000)

Education Council Director
Karen Reczek (2nd term) (National Institute of Standards and Technology)

Membership Council Director
Muhammad Ali (NEMA)