A Case Study on How Insulated Concrete Forms Can Prevent Structure Loss During Wildfires

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ICFs are a building material with unique thermal insulating and non-combustible properties that have shown great potential at protecting a structure during a wildfire. To prove the hypothesis that ICFs can effectively prevent structure damage or loss during a wildfire, an analytical case study on an ICF home that survived the Camp Fire was conducted. The goal was to understand how ICFs unique thermal insulating and non-combustible properties protect structures from wildfires and how this assembly system can be a lot more effective than a traditional frame structure. Additional objectives for the project included highlighting the growing threat of wildfires to promote innovative solutions like ICFs, analyzing wildfire characteristics, examining the factors that cause a structure to ignite, and exploring all the aspects that make a structure fire resistant. Qualitative research was conducted through semi-structured personal interviews with experts in the ICF industry, Cal Fire, and project team members. The results of the interviews were analyzed which proved the hypothesis and showed a correlation between ICF wall assemblies and the structures ability to survive the Camp Fire. The paper also summaries the need for future research to provide further evidence for ICFs' effectiveness at protecting structures from wildfires.

Key Words: Insulated Concrete Forms, Wildfires, Fire Resilient Structures, Non-combustible, Wildland Urban Interface

Introduction

Wildland fires have always posed a threat in California. However, the scale, intensity, and frequency of wildfires have increased profoundly over the last several years. In 2017 and 2018, California recorded two of the most extreme and destructive wildfire seasons. Moreover, in November of 2018, the Camp Fire in Butte County was the deadliest and most destructive wildfire in the history of California. Population growth and increased development have also led to an expanding urban footprint, which increases the wildland-urban interface. This is where structures intermix with undeveloped wildland vegetation and where structures are most susceptible to damage or loss from a wildfire. The increasing intensity and duration of fire seasons along with the rapid expansion of the wildland-urban interface greatly increases the risk to property and life. To combat the increasing threat of wildfires, stakeholders in fire prone regions are deploying innovate strategies to mitigate the risk to life and property.

One of these innovative strategies involves using building materials such as insulated concrete forms. Early versions of ICFs have been around since the 1940's, but the technology has improved substantially. It is an assembly system comprised of rigid thermal insulation made from expanded polystyrene (EPS) foam that serves as the formwork for the reinforced concrete. The rigid thermal insulation has a tight interlocking pattern that firmly holds the forms in place. The EPS forms stay in place after the concrete is poured and serve as the permanent substrate for the interior and exterior, sandwiching the reinforced concrete. This product is already popular in hurricane prone regions because of their extreme water resistance and ability to survive extremely high winds. ICFs have been

slowly gaining popularity to defend structures from wildfires. Furthermore, there is evidence to suggest that ICFs' unique thermal insulating and non-combustible properties have an ability to greatly improve a structures capacity to withstand a natural disaster such as a wildfire.

In order to prove the hypothesis that ICFs can effectively prevent structure damage or loss during a wildfire, an analytical case study was conducted on a home in Butte County, California that survived the destructive Campfire. The home was recently constructed with Logix ICF blocks for the wall assembly. The goal was to understand how ICFs thermal insulating and non-combustible properties work to protect structures from wildfires and how ICF assemblies are more effective than a traditional frame structure. Research was conducted to gain enough background knowledge on the subject in order to uncover the complexities that contribute to a structure's ability to withstand a wildfire. Testing results that demonstrate ICFs flame and thermal resistance were outlined to further understand why ICFs are uniquely capable of defending structures from wildfires. Qualitative research was then conducted through semi-structured interviews with a variety of experts. These included experts and representatives from ICF brands, Cal Fire, and project team members involved in the home being studied. The interviews focused on the individual's experience regarding the Camp Fire and the ICF home in Butte County. The results were then analyzed to find how the home's ICF wall assemblies prevented the wildfire from igniting the structure. Other factors that contributed to the home's success in the wildfire were also highlighted to illustrate the need for stakeholders to address all the various aspects that prevent structure damage or loss during a wildfire.

General Background

The Increased Threat of Wildfires

The severity of a given wildfire season is determined by several climate driven factors, including: "weather, temperature, wind speed and direction, and the presence of combustible material" (Arita, 2018, p.32). These climate driven factors that contribute to the severity of wildfires have become more extreme and volatile. Furthermore, California's annual temperatures have been "increasing substantially during the past four decades and are expected to continue warming this century," which allows for longer and more severe fire seasons (Bedsworth, 2018, p.133).

Population growth and increased development have also led to an expanding urban footprint, which increases the wildland-urban interface (Radeloff, 2018). According to the U.S. Forest Service, the wildland-urban interface (WUI) "is the area where houses meet or intermingle with undeveloped wildland vegetation" (Radeloff, 2018, p.1). The wildland-urban interface is where structures are most vulnerable and susceptible to damage or loss from wildfires. From 1990 to 2010, the WUI in the United States rapidly increased "in terms of both number of new houses (from 30.8 to 43.4 million; 41% growth) and land area (from 581,000 to 770,000 km^2; 33% growth), making it the fastest growing land use type in the continuous United States" (Radeloff, 2018, p.1).

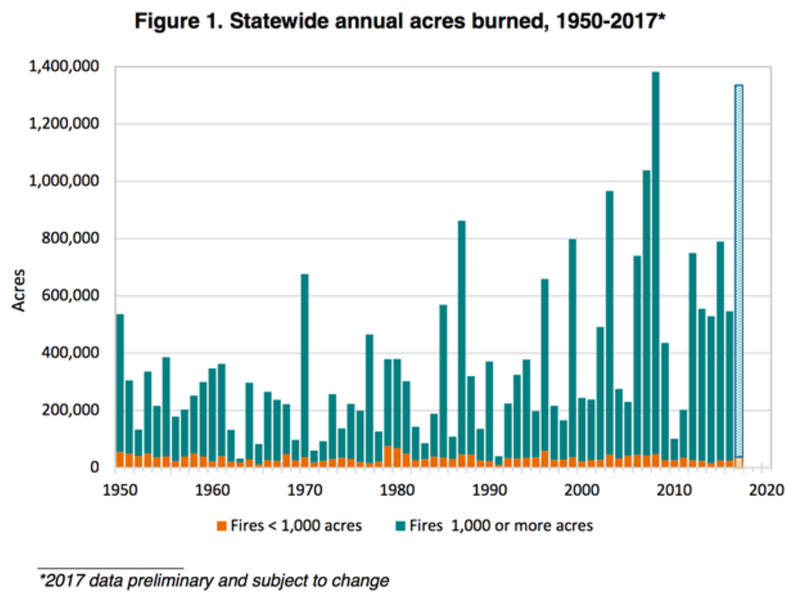

Figure 1. California Annual Acres Burned (Sapsis and Westerling, 2018)

Creating a Wildland Fire Resistant Home

Defending a structure in the WUI from a wildfire is complex and multifaceted. One specific building material will never be the full solution and stakeholders must address all aspects of a structure to prevent damage or loss during a wildfire. The design, materials, and landscaping of a structure all contribute to its ability to withstand a wildfire. The various aspects that protect a structure can be organized into the following categories: defensible space, building materials, glazing, penetrations, and roof design. If just one of these aspects is overlooked the structure will likely be compromised. ICFs are a building material that has shown great potential in contributing to a structure's ability to survive a wildfire. In order to optimize ICFs' fire resistance, a structure must also implement the other aspects outlined above.

How a Structure Ignites during a Wildfire

Embers, direct flame contact, and heat radiation are the three primary ways a structure ignites during a wildfire. Embers are the tiny pieces of burning material from the fire that are transported by wind. Wind events commonly accompany wildland fires, but wildland fires can also create their own wind events known as fire whirls. Wind driven embers or firebands can travel over a mile ahead from the original fire. These embers then create spot fires when they land on combustible materials. Embers can also directly ignite a structure if the building materials are combustible or if they enter the structure through unscreened openings or vents. Embers from wildfires are responsible for many structures igniting. When the main flame front approaches direct flames can meet the structure causing it to ignite as well. However, the passing flame front is not responsible for igniting many structures because the main body of the fire and flame front often passes through an area relatively quickly typically between 1-10 minutes. Even when flames do not physically reach the structure, the

immense heat can transfer to the structure by radiation causing the structure to ignite. Forest fires produce a tremendous amount of heat causing radiant heat to travel in all directions. When the wildland fire reaches a neighborhood, the radiant heat from adjacent burning buildings or spot fires can cause a structure to ignite even when there is no direct flame contact.

ICFs Low Flame Spread and Non-Combustible Properties

ICFs' exterior finishes, rigid thermal insulation, and concrete cavity composition make them extremely flame resistant. Concrete is naturally fire resistant because its material properties are non-combustible. As a result, concrete cannot catch fire. ICFs' concrete cavity is commonly six to eight inches thick and this cavity serves as a fireproof core protecting the structure from the flames during a wildfire. The rigid thermal insulation in an ICF is comprised of EPS foam. A fire retardant is added to the bead before the foam is expanded and molded. This process ensures the insulation is not a fuel source for the fire. EPS foam will not ignite or burn instead it will melt when exposed to extreme heat (Build Block, 2015). Building with ICFs allows for the installation of a wide variety of exterior finishes. However, there are certain durability and flame-resistant qualities shared between the most commonly used and easily installed exterior finishes on ICF walls which include: masonry veneers, stucco, and fiber cement siding. Unlike traditional frame walls, stucco and similar exterior finishes can often be installed directly over an ICF wall above grade without the installation of a membrane. These exterior cladding options commonly used on ICF walls are non-combustible, therefore they do not contribute to the spread of the flames or allow for embers to ignite on the exterior.

The American Society for Testing and Materials (ASTM) Test Method E-84 is also commonly referred to as the Steiner tunnel test, measures how far and fast flames spread across the surface of the material being tested. A flame spread index (FSI) is given on a scale from 0-200; inorganic noncombustible materials are at the bottom of the scale at 0 and organic combustible materials are at the top of the scale at 200. This scale is broken down into three classes: Class A is at the lowest end of the spectrum and Class C is at the highest of the FSI spectrum. All these materials in an ICF assembly are classified as Class A, with an FSI of 0-25. In contrast a typical untreated wood-framed structure assembly has materials classified as Class C with an FSI of 76-200. The Portland Cement Association (PCA), conducted a flame spread test with various ICF foams and found that "the flames travel about one-fifth as far down a tunnel lined with ICF foams as they spread down a tunnel lined with wood" (Portland Cement Association, 2006). Moreover, all the materials used in a common ICF wall assembly are comprised of inherently noncombustible or are treated with fire-retardants to make them extremely fire resistant and ensure they do not contribute to the spread of flames.

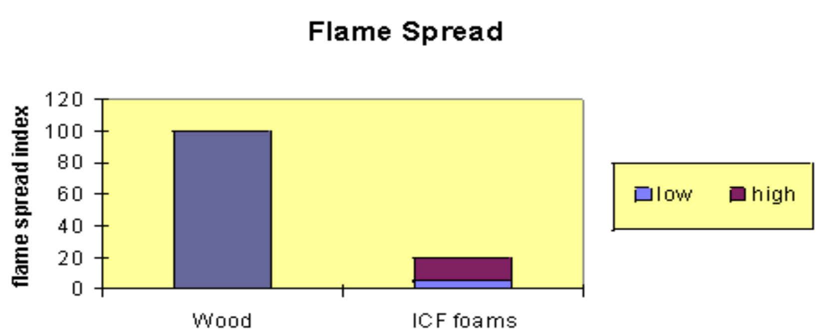

Figure 2. ASTM E-84 Test Results Comparing the SPI of Wood to ICF Foams from Leading Manufactures (Portland Cement Association, 2006)

ICFs Insulation Properties

The dual layers of EPS foam insulation sandwiched between reinforced concrete in an ICF wall makes the assembly capable of providing enough thermal insulation to resist the level of heat transfer that could cause the interior of the structure to ignite. These thermal insulting properties of the ICFs' multi-layered assembly make this product uniquely capable of protecting a structure from the immense radiant heat or direct flame contact in a wildfire. Even a structure built with non-combustible materials could still allow enough heat to transfer to the inside of the structure causing flammable interior finishes like furniture or curtains to ignite. In an ICF wall assembly the fire must breach and travel through four layers to ignite the inside of the structure. The fire must first heat the exterior finishes which are often non-combustible to a high enough temperature to cause ignition of the first continuous layer of 2-5/8 inch thick EPS foam which is treated with a fire-retardant. The EPS foam must then transfer enough heat to a reinforced concrete core commonly 6 to 8 inches thick. Concrete is one of the most heat resistant materials and will significantly slow down the conduction of heat from the exterior to the interior of the wall (Portland Cement Association, 2006). Finally, the fire must still transfer enough heat through the concrete to the inside EPS foam layer to ignite the interior drywall or finishes. ICF walls also differ from typical frame walls because they have a monolithic and continuous layer of EPS foam insulation. This helps regulate temperature and ensure there will not be any gaps in the insulation. Typical frame walls have voids in the insulation along the studs and this can cause thermal bridging to occur, which allows for a pathway of heat to travel through a wall.

The ASTM E-119 test also referred to as the fire-wall test measures the duration of a certain building element's ability to "contain a fire, retain [its] structural integrity, or exhibit both properties during a predetermined test exposure" (ASTM, 2019). In these fire-wall tests, monolithic ICF walls of leading brands were exposed to continuous gas flames with temperatures up to 2,000 degrees Fahrenheit for up to 4 hours. None of these leading ICF brand walls ever failed structurally (Portland Cement Association, 2006). Part of the test also measures if the wall slows the passage of heat and fire from the flame side to the other side. ICF walls did not allow flames or enough heat to pass through the wall to start a fire for up to 4 hours (Portland Cement Association, 2006). To compare, a typical wood framed wall will collapse in an hour or less and allows enough heat to pass through the wall to start a fire on the interior side of the wall. The 4-hour fire rating of a typical 6 to 8-inch ICF block is double the minimum two-hour code requirement.

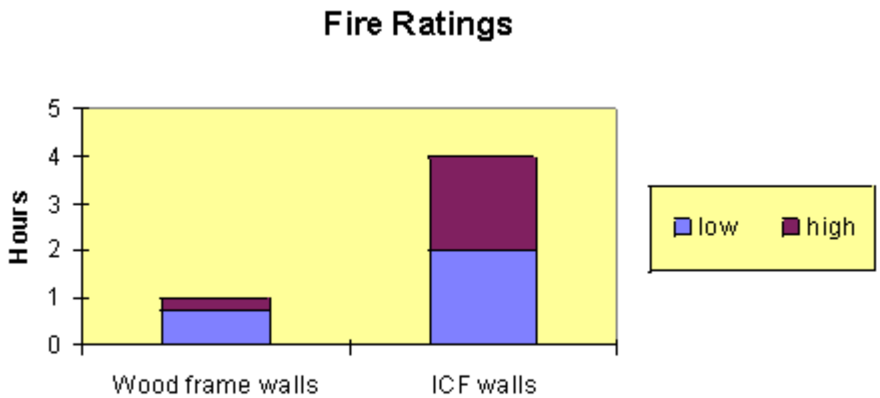

Figure 3. ASTM E-119 Test Results Comparing the Fire Ratings of Wood Frame Walls to ICF Walls from Leading Manufactures (Portland Cement Association, 2006)

Objectives

- Discover scientific data, testing results, and first-hand testimonials to prove the hypothesis that ICFs are effective at protecting structure damage or loss from wildfires.
- Uncover the various factors that contribute to a structure's ability to withstand a wildfire.
- Shed light on the growing threat of wildfires so all stakeholders in the construction industry prioritize fire safety and the use of innovative materials like ICFs.
- Publicize the findings of the research in order to promote ICFs to builders, architects, and owners.
- Make suggestions for future research to collect more tangible evidence on ICFs' ability to address the threat of structure damage or loss from wildfires.

Methodology

An extensive literature review was conducted to gain enough background knowledge on the subject to uncover the complexities and nuances of the project topic. Additionally, unstructured exploratory interviews were conducted at the beginning of the qualitative research with representatives from Logix and Cal Fire. These were informal exploratory interviews over the phone and consisted of open-ended questions to obtain further background knowledge and get a sense of the direction of the responses in order to better formulate and structure the formal semi-structured interviews.

Two documents with a mix of open and closed ended questions were then created. One was structured for Logix ICF representatives, Build Fire Safe consultants on the project, and project team members. The documents were then emailed to the interviewees prior to a scheduled video conference interview. These questions focused on the project's details, goals, other factors that protected the home, and the extent of the damage. Moreover, there were questions on individual's attitudes of the ICFs' performance in protecting the home from the Camp Fire and how ICFs specially prevented the structure from igniting. The other document was structured for wildfire experts from the northern

division of Cal Fire. These interviews were focused on the Camp Fire's characteristics, timeline, and destruction in the approximate location of the home being studied.

Case Study

On the morning of November 8th, 2018, the Camp Fire was ignited by a faulty electrical transmission line (Cal Fire, 2019). Strong easterly winds quickly drove the fire westward and downhill to the developed areas in and around the town of Paradise. As mentioned above, the Camp Fire turned into the deadliest and most destructive wildfire in California history. The fire burned for 17 days and tragically burned 153,366 acres, destroyed 18,804 structures, and killed 85 civilians (Cal Fire, 2019). Miraculously, a single-family home just west and downwind of the town of Paradise survived the destructive wildfire. The home was recently built with Logix ICFs and was one of the few structures in the area that survived this deadly fast-moving wildfire.

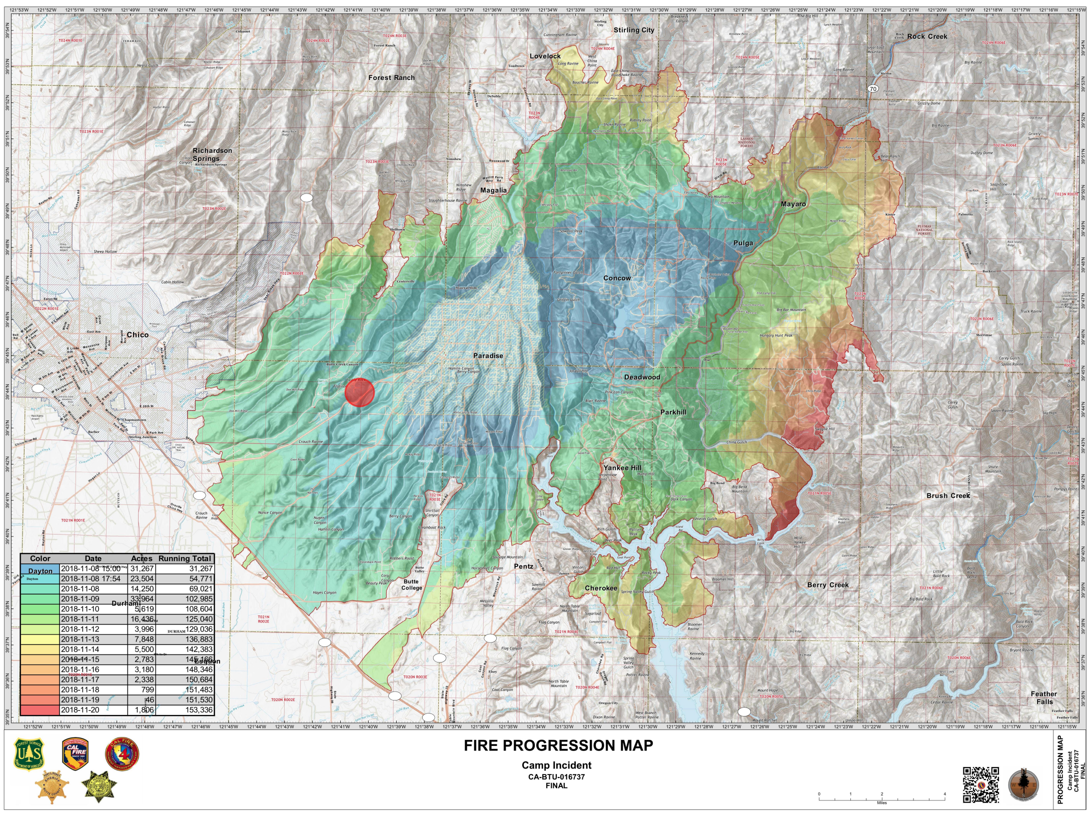

Figure 4. Fire Progression Map Camp Fire Incident, Red Circle Indicates Approximate Location of Home. (Cal Fire, 2019)

Project Details

- Location: Cliffhanger Lane, Butte County, California
- Project Completion: 2016
- Cost: Roughly the same as a similar wood framed design

- 6” ICF Logix Blocks
- Stucco Exterior Façade
- Laminated Veneer Lumber (LVL) framed roof
- Thermoplastic polyolefin (TPO) roofing membrane

Other Factors that Protected the Home

- Defensible space around the perimeter
- Non-combustible landscaping and hardscaping
- Limited screened openings and vents in the roof
- Landscape sprinkler irrigation system was turned on
- Metal retaining wall blocked embers
- Fire-rated glazing

Project Goals and ICF selection

The client went on to the Logix website and saw a blog post on ICFs saving a home during Hurricane Sandy. She was inspired by ICFs' ability to create natural disaster resistant structures and choose ICFs based on this unique quality. Although, California does not have hurricanes, the state and especially the region of northern California where the home is located is no stranger to natural disasters and has seen earthquakes, wildfires, floods, landslides, and mudslides. The client was able to help meet their goal of creating a natural disaster resistant structure by selecting ICFs wall assemblies in the construction of her new home.

Figure 5. Logix ICF Home on Cliffhanger Lane that Survived the Camp Fire (Lennox, 2019)

How ICFs Prevented Structure Loss

The Camp Fire was a very aggressive fast-moving fire that reached the home on Cliffhanger Lane around 8:00am the same morning the fire broke out. The home was showered in wind driven embers and flames physically met the structure as well. Even though the home had a defensible space and featured non-combustible landscaping, decretive landscape bark caused the fire to physically reach the house and burn for a sustained amount of time. A typical wildland fire can cause temperatures to reach 1,472 degrees Fahrenheit near the forest floor and up to 2,192 degrees Fahrenheit in extreme conditions at the flame front. Based on the fire characteristics and the available fuels in the area as well as the landscaping it is likely the fire reached temperature of 1,472 degrees Fabrinet or more. The home's underground plastic septic system melted, and a pump house framed from wood on the property completely burned down. Kent Yonker at Build Fire Safe California, who has over 20 years working with ICFs and is also a Northern California sales representative for Logix, stated that in his opinion if the walls would have been framed from wood with OSB or plywood sheathing that the structure would have likely burned down because the fire sat there long enough to severely singe the stucco exterior. Most of the opinions of interviewees concluded that they believed ICFs played a crucial role in preventing the structure from igniting. Although this immense sustained heat caused damage to the exterior stucco façade, the 6" Logix ICF wall assembly features a 3-hour fire rating and the EPS insulation has a SPI of less than 25. These qualities prevented the flames from spreading or enough heat to transfer to ignite a fire on the inside of the wall saving the structure from ignition from the immense heat and direct flame contact.

Conclusion

In conclusion, ICFs unique thermal insulating and non-combustible properties have shown they can protect structures from wildfires. As illustrated in the analysis of the ICF home that survived the Camp Fire, ICFs are extremely effective and can provide a robust defense against direct flame contact and radiant heat from wildfires when combined with a fire smart design, materials, and landscaping. ICFs' properties give a structure a superior chance to survive a wildfire compared to traditional wood framed structures. In fact, out of all the experts interviewed only one individual stated that they have seen an ICF structure fail during a wildfire, but this was due to lack of any defensible space around the perimeter. There are many examples of ICF structures surviving wildfires when neighboring traditional wood framed structures are completely burned to the ground. Moreover, initial evidence demonstrates their effectiveness, but further research should take place to further promote and prove ICFs' capabilities of protecting structures during wildfires.

Further Research

A database that tracks ICF structures success in wildfires would provide more evidence and understanding of their ability to prevent structure loss or damage during wildfires. The database could incorporate the structure's location, design, specific ICF product, the extent of the damage, and the wildfire characteristics experienced by the structure. This database would provide historical evidence that could further validate ICFs' effectiveness. It would also allow stakeholders to see which ICF products and designs are most effective. This would ultimately lead to more effective and fire resistant ICF structures while also promoting them in order to increase their popularity, saving even more structures from wildfires.

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