When Nature Strikes: A Study of Beetle Kill in America and its Potential Use for Mass Timber Construction

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This paper explores the alternative methods of wood collection in respect to lumber provided by nature and its potential use for mass timber construction. Sustainability in terms of materials can be compared through a complete life cycle analysis, which factors in pollution, waste, resources, and energy required for manufacture. In comparison to steel or concrete construction, wood outperforms the competition and it supports the atmosphere through its natural cycle of growth. In addition to sustainability, wood can be recycled and reused as other building materials, decorative elements, biofuel, and landscaping products. Recovered and recycled wood in the use of new stick frame construction has been understood as undesirable, but when used in mass timber construction, it eliminates the need for pieces of the same length and the nature of mass timber allows pieces that may not be suitable for structure to be combined and reinforced.

An alternative source of wood is provided by natural disasters, such as hurricanes, earthquakes, and tornadoes. The extent of the damage determines a tree's use, but ultimately these trees are suitable in mass timber construction. In addition to natural disasters, diseases and pests can cause a significant amount of damage, ranging from mild affliction to mass destruction. Many diseases and pests have swept through the United States claiming species of trees since European settlement.

Beetles make up the largest order in the animal kingdom, with only 24 species of beetles active in the United States causing damage to trees. Bark and borer beetles are the most destructive, affect the heart and woody areas of a tree. America is currently experiencing an epidemic of Mountain Pine beetle, Southern Pine beetle, Ips beetle, and most recently the Emerald Ash borer.

The Emerald Ash borer is a highly invasive species and an estimated 34 million ash trees, in a 25 state area, expected to be removed and replaced by 2019. The mass timber industry has the opportunity to capitalize on this surplus of wood as beetles can weaken the it, making it unsuitable for stick frame construction. Beetle kill wood, until recently, has mainly been used for biofuel, decorative, and small scale hobbies. Alpine Timberframe and Design has worked with beetle kill wood in their construction of UBC's Bioenergy Research and Demonstration Facility and the Student Union Building, also at UBC. Euclid, along with the University of Utah, has been using beetle kill wood in a new form of mass timber construction called ICLT, interlocking cross-laminated timber, which uses no fasteners or glues. ICLT can be produced by any timber fabricator wishing to diversify their product without adding additional infrastructure. Mass timber construction can become affordable for smaller scale projects and housing without the need to harvest virgin trees when recycled wood, wood provided by nature, or beetle kill surpluses are used.

INTRODUCTION

On May 18th 1980, a magnitude 5.1 earthquake struck directly below the northern slope of Mount Saint Helens[1] where a cryptodome had formed as a result of increased volcanic activity. The earthquake caused the cryptodome to plummet down the face of the mountain which created the largest recorded landslide in history. The collapse of the cryptodome and the northern face exposed the interior of Mount Saint Helens to a lower pressure which caused a lateral blast, reaching up to 670 miles per hour,[2] to knock down 230 square miles of forest and the extreme heat destroyed miles more of trees past the knock down zone. The eruption of Mount Saint Helens damaged or destroyed more than four billion board feet of timber and only 25% of these felled trees were

recovered. The devastation from the eruption resulted in a positive outcome of large volumes of timber for the use in construction and wood by-products. Based on the 21,000 board feet of framing and wood products that an average 1,660 square foot 1980's home required,[3] a total of 47,619 homes could have been built from this natural disaster.

SUSTAINABLE RESOURCE

A sustainable resource is something whose production is supported by nature, being consumed at the same rate that it can be renewed. Timber is a sustainable resource and when considered over its complete Life Cycle Assessment, wood outperforms other building materials such as steel and concrete. The Canadian Wood Council conducted a comparison of 2,400 square foot homes built of wood, steel, and concrete over the first twenty years of their lifespans. "Relative to the wood design, the steel and concrete designs: release 24% and 47% more air pollution, produce 8% and 23% more solid wastes, use 11% and 81% more resources, require 26% and 57% more energy to produce, emit 34% and 81% more greenhouse gases, and discharge 4 and 3.5 times more water pollution"[4] In addition to leaving the smallest carbon foot print of the three materials, a growing forest supports the atmosphere by producing 1 ton of oxygen and absorbs 1.4 tons of carbon dioxide for every 1 ton of wood. The absorption of carbon dioxide traps it in the trees' fibers and a 2,400 square foot wood-frame home will lock in 28.5 tons of carbon dioxide, which is equal to seven years' worth of emissions from a small car.

As a tree ages, its absorption of carbon dioxide slows, making it a candidate for timber production and making room for young trees with faster absorption rates.[5] In the United States, American landowners plant more than two billion trees every year and with the addition of natural reseeding, America is now covered 33.3% by forestry and has continuously exceed harvest since 1940. It is one of the healthiest and most productive forest lands in the world.[6]

In comparison to stick-framed construction, mass timber uses 30% less of harvested virgin trees because the majority of the tree can be used and not wasted as is the case with stick-framed lumber. A healthy and growing forest provides an abundant sustainable resource that can be used for the advancement of mass timber construction.

WOOD WASTE AND RECYCLING

Timber recycling is the practice of taking wood waste and turning it into a usable product. This practice became popularized in the early 1990's when issues of deforestation and climate change pushed suppliers and consumers to find a more sustainable source. Wood harvested from the United States accounts for 70% of the volume of lumber used in construction and the remaining 30% of lumber is imported.[7] Of this volume that the United States utilizes, a total of 127.5 million tons of wood waste is generated from demolition, municipal solid waste, new construction, and lumber manufacturing.[8] An estimated 102.9 million tons of wood waste is potentially recoverable but only 78.7 million tons is currently being recycled.[9] Approximately 30% of wood in a deconstructed building can be used as it or re-planed for future lumber[10] while the rest can be used for resale as ornamentation, landscaping products, chips for footpaths, or biomass fuel.[11] "Added value" markets for reclaimed items such as architectural trimmings, antique hardwood, and vintage pieces are becoming prevalent and the demand for reclaimed lumber is growing.[12] Based on the average home size of 2,400 square feet and the mass method of calculation,[13] a total of 1,480,190 homes could be built a year using solely recycled and reclaimed lumber in the production of mass timber homes.

LUMBER PROVIDED BY NATURAL DISASTER

Not all manufactured lumber is from recycling or harvesting forests, in the case of Mount Saint Helens, a natural disaster can provide a substantial amount of timber. Natural causes such as hurricanes, tornadoes, ice storms, volcanic eruptions, and earthquakes can cause extensive forest damage by breakage, uprooting, wounding, and bending, leaving behind trees that may be harvested for timber. The amount and type of damage determine a tree's use after harvest, with a range of options from small chip products and paper to structural timber and logs. Breakage is the most common type of storm damage and the most difficult to make into dimensional lumber due to the variety of lengths the breakage can create. Uprooted trees are an ideal source for lumber, but the longer it remains unharvested, the more likely it will be degraded by stains, decay, and insects. Wounds and splits, caused by adjacent trees, major branch breakage, lighting, or frost cracks, are types of damage that usually do not require immediate harvesting unless the damage is significant. In that situation, an extremely wounded or split tree can still be used for lumber, so long as the logs are milled parallel to the damage. Damaged trees must be harvested within a year due to the invasion of bark beetles, wood borers, and fungi. If not cleared early enough the damage caused by the invading pests and fungi will allow decay fungi to set in and the tree becomes unusable for lumber.[14] Harvesting these trees is beneficial to mass timber since it requires a volume of timber to be assembled into one panel or beam. Each piece doesn't need to be perfectly the same length with the use of tongue and groove and lap joints to make multiple pieces into one.

PESTS AND DISEASES AFFECTING FORESTS

Almost 500 pests and disease causing pathogens, not native to the United States, have been introduced to the land in the last 400 years since European settlement, most arriving on imported products of plants or packaging. The Chestnut Blight has nearly eliminated all mature American chestnuts; White Pine Blister Rust has reduced the population of western pines, with the greatest threat to those in higher altitudes, which protect the snow cover; and more than one million tanoak and oak trees have succumbed to Sudden Oak Death in the mountainous regions of California and Oregon, where a large amount of tree and shrub species are vulnerable.[15]

Heart-rot, root-rot, cankers, rusts, and wilts make up the broad categories of disease that affect trees.[16] There are 32 common subcategories of tree pathogens in the United States[17] that are affecting the forestry and causing early harvest of infected trees. These trees can usually be harvested for lumber if the damage is caught in time; the method of destruction and how quickly the ailment sets in vary for each instance, and the amount and type of damage determine how much of the wood

can be manufactured into lumber. Many trees require large pieces to be discarded due to too much damage or infestation.

The Northeastern states that have been trading with Europe and Asia since the colonies were settled has the most established non-native tree-killing pests ranging from 62 species in New York to 55 species in New Jersey. The Western costal states are seeing a rise in their number of species with 42 in California, 41 in Washington, and 36 in Oregon.[18] Pests can be categorized into defoliators, root-feeding insects, terminal-feeding insects, sucking insects, bark beetles, and wood borers. Defoliators, such as caterpillars and webworms, feed on the leaves and needles of a tree, and in the case of a large population, can completely remove the foliage. Most broad-leaved and deciduous trees can survive defoliation for several years before they die. Root-feeding and terminal-feeding insects, such as wire worms, white grubs, and weevils, feed on tree roots and the meristem tissue, potentially causing death or stunting the growth of a tree and causing deformities resulting in crooked trunks unsuitable for dimensional lumber. Sucking insects like aphids, mites, and cicadas have a mouth designed to penetrate young shoots, twigs, and foliage in order to feed on the resin and sap of a tree. Growth rates of trees can be reduced if a large concentration of these insects is present. Some trees like the white pine can die due to the rapidly growing black spores of a fungus attracted to the secretion of the sucking insects.[19]

Disease and infestation in a forest can not only spread, but more often than not, bring other ailments that attack an affected tree. Most trees die due to multiple factors that have a cause and effect on one another. The amount of lumber that can be salvaged, while less than that of felling a virgin tree, can contribute to mass timber construction, due to the fact that mass timber uses more of a tree than dimensional lumber.

BEETLE INFESTATION

For every four species of animals in the animal kingdom there is one beetle. The Coleoptera order is the largest order in the animal kingdom containing 350,000 species worldwide. There are 84 species present in North America that vary in size, color, shape, and diet. Only 24 species, present in North America, use trees for feeding and breeding, causing damage to their host trees.[20] Bark beetles bore a hole into the bark of a tree and tunnels are cut between the woody area of the tree trunk and the bark of the tree. The females lay their eggs inside of entrance tunnels or galleries of tunnels for the larvae to feed on the phloem and xylem tissues of the tree. When the beetles completely girdle the tree beneath the bark, it interrupts the flow of nutrients necessary for the tree to live, eventually killing the tree. Healthy trees are set up with a defense mechanism of saps and resins which flood the tunnels causing the beetles to drown, but trees past maturity are more vulnerable than young trees. Some bark beetles carry disease organisms in their bodies, distributing them as they migrate from tree to tree, such as the Dutch Elm disease, which killed nearly all American Elm trees in many North American regions.

Wood borers are similar to bark beetles, but they attack the heartwood and sapwood of weakened trees or trees past maturity. Some species will even attack unprocessed harvested wood. Wood borers are the most damaging insect pest to North America and they damage trees by tunneling into mature wood as they feed. The eggs of wood borers are deposited in cuts of the bark and after hatching, the larvae will burrow into the phloem tissue, eventually working their way through the woody tissue into the heart of the tree. Pine, spruce, fir, birch, apple, black walnut, and ash trees are the primary trees affected by wood borers.[21] Pine, an inexpensive material, and fir, making up 25% of all lumber produced, are two popular materials for construction and spruce is often used for interior construction.[22] The other species being affected are primarily used for decorative applications, millwork, and furniture. With the abundance of material created by beetles, beetle kill wood could create inexpensive products and housing.

SERIOUS PESTS

Over the decades of American growth, beetles have been slowly invading the country, creating surges of epidemics over the years. Since the late 1990's, after long periods of draught, beetles have surged again into an epidemic. The Mountain Pine beetle, active since 1996, is currently affecting Colorado and Wyoming with more than 1.5 million acres of forest affected so far, resulting in an average of 75,000 acres and 6.3 billion board feet a year. By 2012 the beetles have spread and killed almost all the mature lodgepole trees in northern Colorado and southern Wyoming.[23] Another serious pest is the Southern Pine beetle covering a range from Pennsylvania and New Jersey to Texas and from Arizona and New Mexico to Nicaragua. The average annual tree mortality from the Southern Pine beetle in the US often exceeds 100 million board feet of timber.[24] Coming in behind the Southern Pine beetle is the Ips beetle, an engraver beetle primarily located in the southeastern region of the US. The Ips beetle, in a wide spread outbreak, can damage enough trees to produce 1.1 million board feet in a year.[25] This beetle causes the least amount of damage in comparison to the Mountain and Southern Pine beetles, but even in small swaths it can fell enough trees to contribute to the mass timber market.

A contender for the most destructive beetle has been slowly making its way across the United States; "the Emerald Ash borer is a highly invasive species, capable of populating a large area in a very short amount of time."[26] It was first discovered in the United States in 2002, in Michigan, and has spread to 27 states since, with Nebraska being the most recent in 2016.[27] In a simulated study by the USDA Forest Service, which focused on established communities in a 25-state area, it was estimated that there are 38 million landscape ash trees and of this 38 million, an estimated 34 million ash trees will be removed and replaced between 2009 and 2019.[28] Based on an average height of 65 feet and an average diameter of 30 inches,[29] these trees would create 40.1 billion board feet of lumber,[30] an average total of 4 billion board feet a year.

From these four types of beetles, approximately 10.4 billion board feet a year can be used to create mass timber housing. This volume of lumber would create 346,666 average sized, mass timber homes a year. With the current volumes of wood being produced from beetles and the projected amount of trees the Emerald Ash borer will affect, beetle kill wood is a prime candidate as a sustainable resource for mass timber construction.

MASS TIMBER

Mass timber is a type of framing style that utilizes large panels of solid wood in construction. Cross-laminated timber (CLT), nail laminated timber (NLT), and glue laminated timber (glulam) are included under the mass timber category. These products are sustainable, carbon efficient, and cost-competitive with other widely used building materials. These products were created using scientific data from fire, seismic, durability, acoustic, and vibration tests to be candidates for construction applications that currently implement concrete and steel.[31] "Tall wood buildings are capturing the imagination of architects, engineers and developers, who see them as a way to lessen the carbon footprint of the built environment while demonstrating ingenuity and meeting the same standards for safety and performance as any building type." With the movement of reducing carbon footprints and the refocus on the environmental benefits of wood, advancements are being made in wood technology and manufacture to make mass timber buildings possible, safe, and cost effective.[32]

CROSS-LAMINATED TIMBER

CLT is made by gluing alternating layers of lumber together to make a thick panel to provide stability, strength, and rigidity. It offers speed and efficiency at installation, reduces on-site wood waste, offers design flexibility, is energy efficient, environmentally sustainable, and uses resources efficiently. CLT uses more of a tree than dimensional lumber and can use smaller dimension material that couldn't be used in other structural construction. Each panel of CLT is made specifically for a project resulting in almost no jobsite waste and any waste created can be used for stairs, other architectural elements, or biofuel.[33]

Pine, the leading tree affected by beetles, is softened when attacked by beetles and dyed a grey blue color by fungi that sets in after the beetles have made their tunnels. Until 2008 the industry believed there was little that could be done with the masses of beetle kill pine besides artistic or decorative uses, which was marketed as blue stain or denim pine. Because of its weakened state, traditional construction uses of pine were impossible for beetle kill. In 2011, Alpine Timberframe and Design worked on an innovative construction project at the University of British Columbia which utilized beetle kill pine for more than cosmetic purposes. UBC's Bioenergy Research and Demonstration Facility was named "one of the world's top 100 most innovative and inspiring projects in KPMG's Infrastructure 100 listing." Beetle kill wood was usable in this scale of building due to CLT's cross-wise layering creating rigidity and strength. Lutz, the president of Alpine Timberframe, "believes that beetle-kill wood, which sells for deflated prices because of the amount of beetle-kill timber now on the market, means that CLT panels can be cheaper, opening its use up to other opportunities including in residential construction."[34]

INTERLOCKING CROSS-LAMINATED TIMBER

Beetle kill thus far has been used for very little construction projects besides artistic and decorative applications. It has mainly been used in small scales for hobby crafts and furniture and in large scales for chips/ground material and pellets for burning, which releases the trapped carbon dioxide into the atmosphere. "However use for energy is the lowest value application of this material and it won't cover the cost of removal and transportation." It's more mindful to use the wood for higher value productions, keeping the carbon dioxide trapped, and only using the left overs for energy generation. Euclid Timber, LLC developed a mass timber panel similar to CLT that uses no fasteners and no adhesives and it uses 2-7 layers of cross directional pine from wood waste[35] by dovetail and tongue and groove joinery. This allows the panel to be disassembled at the end of its life to be re-purposed in the building material supply chain. "Utilizing no fasteners or glues also reduces overall capital cost for either stainless fastener purchase and install or press purchase and set up associated with glue lamination. Conversely, standard mills and timber fabricators looking to diversify their product offering may produce ICLT with existing infrastructure and equipment."[36] ICLT allows low-grade wood to be used in high value conditions estimating a use of 100 years compared to the 30-50 year life of light framed construction. ICLT structures can reach nine stories and are potentially affordable for both home and commercial buildings. Research conducted at the University of Utah found that "Forestlands in the intermountain west average 50 trees per acre with an average height of 80' and trunk diameter of 3' at the end of their useful CO2 sequestration life. A mature tree produces 1695 board feet of lumber. A forestland of 1 million acres of standing dead beetle kill pinewood yields 85 billion board feet of material. Put into an ICLT configuration of 40,000 B.F. per average sized house in Utah (2,700 S.F.), this would produce over 2 million housing units. With an estimated 750,000 units to be added by 2030 in Utah alone, the Colorado standing dead forestland for example would provide enough material for most of the U.S. intermountain housing demand."[37]

THE FUTURE OF MASS TIMBER CONSTRUCTION

The epidemic of borer and bark beetles will continue to rise for the foreseeable future and will continue to produce a surplus of timber. This surplus will cause timber prices to fall and beetle kill wood can find its most productive and lucrative use in mass timber construction. From September 2015 to August 2016, a total of 13.8 million new residential construction projects were started with single family homes making up the largest segment of the market.[38] If all the timber produced by beetles per year were to be used in average sized homes (2400 S.F.) and made of CLT or ICLT construction, a total of 346,666 houses could be built. Each of these houses would have an estimated 100-year life and, if constructed of ICLT, the wood could be reused in the lumber market after deconstruction.

Timber provided by natural disasters, recycling wood, and other unexpected sources could potentially provide the needed material for all new residential construction projects and reduce the amount of forestry felled each year. Wood is being revitalized as a construction material and scientific studies addressing safety, loads, and new heights are proving the advantages of mass timber construction over concrete and steel. In many places, such as Europe and Canada, mass timber construction has become as popular as steel and concrete designs due to its industrial manufacturing, prefabrication, and rapid building completion. The recent approval of the 2015 International Building Code has expanded the options for structural applications with wood designs and in the 2015 National Design Specification for wood construction, CLT has been

incorporated in several chapters, including a product chapter specific to CLT. The United States will be seeing a rise in mass timber construction in the coming years as designers and builders become familiar with the structural implications, fire and safety codes, and the height possibilities. In the meantime, wood recycling practices must improve, nature will continue to provide material, and beetle kill wood will remain an abundant resource for mass timber construction.

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