Q Can an intense fire damage a poured concrete or slab foundation?

A *Peter Marxhausen, a forensic structural engineer and civil engineering instructor at the University of Colorado Denver and author of "Engineering Evaluation of Fire Damage to Concrete Foundations"* (Structure*, August 2014, structuremag.org/?p=4102), responds*: Yes, an intense wildfire or structural fire can cause significant damage to a poured-concrete, CMU, or slab-on-grade foundation. The damage is generally associated with structural degradation due to high heat combined with internal nonhomogeneous thermal stresses. With the combination of externally applied forces, internal thermal-induced stresses, and the degradation of the concrete strength, the foundation may continue to stand, or it may collapse.

I have evaluated hundreds of structures that have been damaged by fires, including wildfires **(1)**. Over the past 25 years, I have found that if the structure is wood-framed and burns without being quickly extinguished, the resulting temperature increase can be sufficient to cause irreparable damage to the concrete foundation at the areas of exposure to high heat.

I have also evaluated concrete foundations that have been damaged by ordinary house fires and have always found that the concrete foundation becomes unusable where the structure is burned to ash without the benefit of being extinguished. In those cases where the heat is high for several hours, the exposed concrete becomes soft and powdery and can easily be broken apart with a framing hammer to reveal perfectly intact rebar (which, by the way, doesn't melt in a fire).

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Photos by Peter Marxhausen

In 2012, the Waldo Canyon wildfire near Pikes Peak in Colorado burned more than 18,000 acres of land and destroyed 346 homes. Here, the author surveys some of the damage caused by the fire.

On the other hand, firefighting professionals typically extinguish most structure fires before the concrete is heated to an extent that it becomes weakened. Where a traditional fire response extinguishes a structure fire, the evaluation methods that I discuss below can help determine whether a foundation is safe to be reused in the repair of a structure.

EVALUATION

When I first started evaluating fire-damaged foundations to determine if they were safe to rebuild or needed to be replaced, I would typically obtain concrete cores of the damaged foundation, then submit those samples to a third-party testing agency to conduct a chemical analysis, compressive strength tests, and a microscopic/petrographic analysis. Testing like that would often take four to six weeks and could cost thousands of dollars, depending upon ease of site access and the number of cores to be extracted and evaluated. More recently, I've developed methods for quickly and economically evaluating concrete slabs and foundations for heat and fire damage.

Visual assessment. I look for patterns of scorch marks, heat exposure, cracks, changes in color, and surface spalls. I also look for leaning or tilting of the walls, which may not be due to heat damage but to the loss of diaphragm support after a structure has been consumed by a fire.

Typically, normal concrete is not significantly altered or damaged below a temperature of 500°F; however, rapid heating of the concrete can cause pore water to boil rapidly, which can cause surface spalls. These can also result from sudden cooling and contraction after being sprayed by a firefighter's hose. Spalled areas should be carefully examined to determine whether they are a sign of widespread heat damage or an isolated occurrence that could be addressed with a targeted repair patch.

The color of the concrete paste should also be reviewed since a color change may indicate exposure to temperatures greater than 550°F. Concrete exposed to temperatures greater than approximately 570°F often turns a shade of pink, associated with chemical changes of the iron-containing compounds in the aggregates and paste matrix. At much higher temperatures—which are not commonly encountered during typical structure fires—the concrete can turn back to a light gray and then eventually to a yellowish-brown color. Concrete that has turned pink is damaged and should be replaced **(2)**. Smoke stains and scorch marks can point to areas that were exposed to high heat when compared with areas exposed to less heat, indicating the need for further evaluation.

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Concrete exposed to intense heat often has a pink hue, a strong indicator that it is severely damaged and shouldn't be reused for reconstruction **(2)**. A few strikes with a framing hammer on the corner of this heat-damaged foundation **(3)** were enough to fracture the concrete and expose rebar **(4)**.

Audible changes. Striking various exposed surfaces with a sounding hammer—typically, a framing hammer with a hardened steel handle—and listening to the resulting sound the hammer makes can help differentiate between undamaged and damaged concrete. In general, healthy, undamaged concrete will cause a hammer to have a high-frequency ringing sound when struck. A consistent dull thud or soft noise can indicate damaged or poor-quality concrete.

Fracture mechanics. Healthy, undamaged concrete will typically fracture in a plane through the aggregate. In heat-damaged concrete, the paste matrix is often much weaker than the aggregates; therefore, the fracture plane will break around the aggregate pieces. To facilitate an evaluation of the fracture mechanics, the edge of the concrete can be struck with a framing hammer. Undamaged concrete will typically be difficult to break, which may be an indication there is no damage. By comparison, heat-damaged concrete will crumble away with a few rigorous hits.

A quick way to convince a homeowner who may want to reuse their heat-damaged foundation to choose otherwise is to show them a photograph or two illustrating how easily a few hits with a hammer can dislodge concrete and expose rebar **(3, 4)**.

Relative concrete strength. A Schmidt hammer, also known as a rebound hammer or a Swiss hammer, is a calibrated device that is used to measure the elastic properties or surface strength of concrete. Although the results of the Schmidt hammer test can be used to determine an approximate concrete compressive strength through use of empirical tables, the original as-built design compressive strength is often not known and, therefore, that sole data point is of minimal benefit.

As with nearly all of the aforementioned evaluation methods, especially the Schmidt hammer evaluation, more meaningful data is obtained by a comparison of test results from at least four areas of the foundation. One way to do this is to conduct a Schmidt hammer test below grade at an excavated surface (where it was protected from heat by the soil) or at a lower, inside foundation corner to obtain a baseline value for areas that were exposed to minimal or less heat. If areas of the foundation that were obviously exposed to high heat exhibit a 20% or more decrease in concrete strength compared with areas that were not exposed to heat, those results should be reported to the client and considered in the analysis of whether to reuse the foundation.

In the event that 50% or more of the foundation system exhibits damage, the entire foundation is typically removed and replaced. However, an owner may want to preserve as much of a foundation as possible—for example, if the building is historical or the owner has minimal insurance coverage. In that case, additional evaluation, which would likely include laboratory analysis and/or nondestructive location of the embedded rebar, may be necessary to determine if the structure is safe to support the anticipated loads and what repairs are needed to fortify deficient areas.