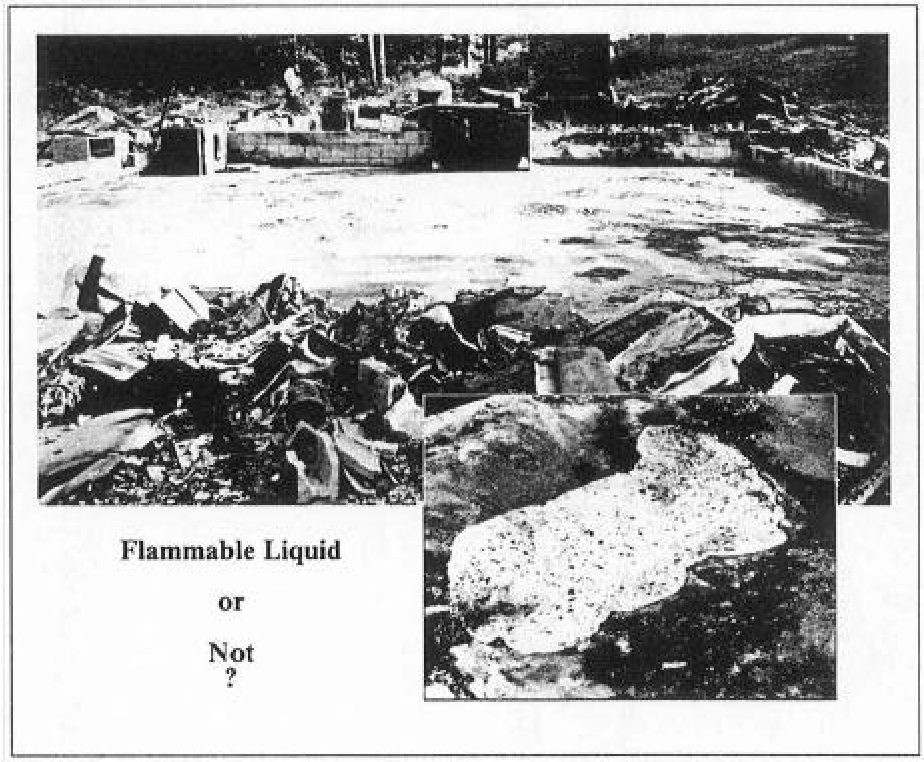
Misconceptions About Fire Investigation

By Carter D. Roberts

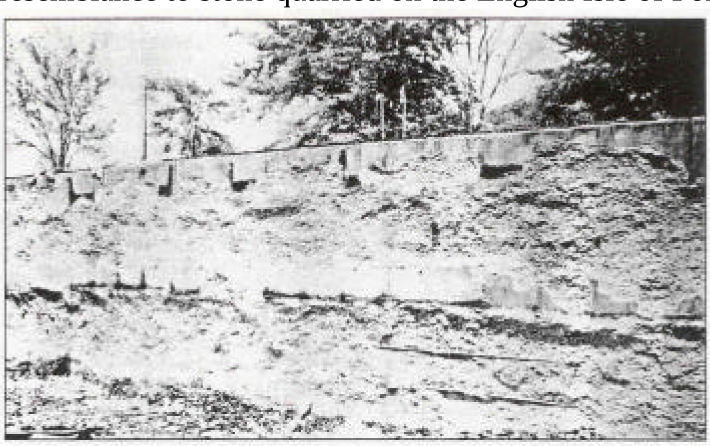
Part III / Spalling



Many old-time Fire investigators will tell you that if **spalling** occurs in fire, an accelerant must have been used. Is here any scientific evidence to support such a position? In order to answer that question, one must know the definition of spalling and the causes of spallation. Misconceptions about spalling often arise because of the failure to understand the most common material used in construction in the United States today – concrete.

Concrete is a mixture of cement, water, and aggregates. First, concrete and cement are words that are not interchangeable. Concrete is to cement as a cake is to flour. Cement paste, a mixture of cement and water, binds together to form a rock like mass.

Portland cement is a manufactured cement and is not a brand. It is spelled with a small "p" because it has nothing to do with either Oregon or Maine but takes its name from its resemblance to stone quarried on the English Isle of Portland.

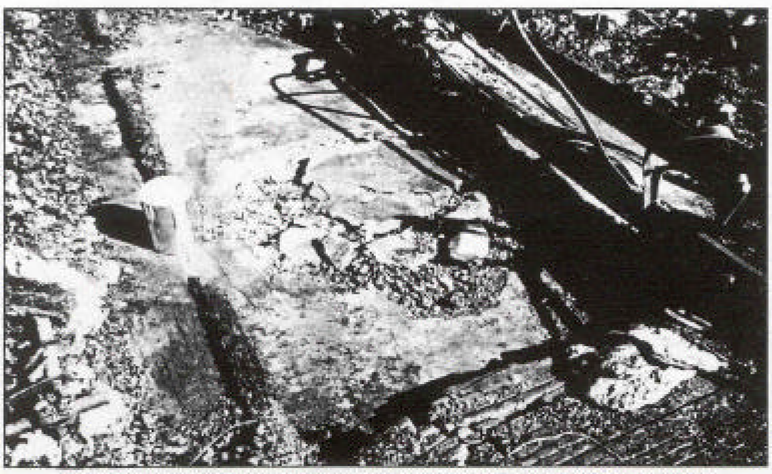


Each of the principal ingredients of concrete—cement, aggregate, and water—is indispensable in making concrete; but each can also negatively affect properties of concrete.

Portland cement is made by cindering finely crushed limestone, marl, shell, or other rock products in huge kilns. The resulting cement clinkers plus a small amount of gypsum (about 3%) are mixed together and ground up again. The gypsum controls the rate of hydration which in turn controls the hardening process when the cement is mixed with water. The final product of these grinding, firing, and mixing process is called "portland cement."

Portland cement paste makes up only about 22 to 38% of the total volume of concrete. The remaining 78 to 62% of concrete can be made of fine aggregates such as sand and course aggregates such as gravel stone.

Fine aggregate, such as sand, ranges in size from one-fourth inch down to particles which will pass through a sieve having 100 openings per linear inch or 10,000 openings per square inch. Course aggregate is well grated or crushed rock and can range from one-fourth inch. Course aggregate should be hard and not flaky and should not contain lumps of clay or organic matter. Also, the mixing water for concrete should be clean and free of acids, alkalies, and other materials detrimental to good cement. Poorly made concrete may crack, craze, scale, and spall under affects of loads or temperature. It can even disintegrate completely.



Some of the most dramatic examples of spalling are thought to be caused by entraped moisture at very high temperatures. Some investigators believe this type of spalling can occur deep in concrete and produce larger, thicker chips, but even that generalization on this subject is very difficult at best.

By adding small quantities of an air-entraining agent at the time of manufacture, concrete can be made to have millions of tiny air bubbles. This results in improved performance of concrete, particularly against the freezing action in the northern climates.

Aggregates used in concrete can vary widely in different parts of the country. The type of aggregate used is a major factor in determining thermal and physical characteristics of concrete, such as thermal conductivity, changes in strength and color, and possible spalling.

Concrete properties are affected by temperatures and aggregate type. It is also interesting to note that dolomitic gravel leads to very good fire resistance in concrete. The reason for this is that the calcinations (occurring at 1100 to 1400 degrees) of the carbon aggregate is endothermic, and as a result, heat is absorbed and a further temperature rise is often delayed.

Although the type of aggregate used in concrete plays a major role when concrete gets exposed to high temperatures, it is not the only factor in determining the behavior of concrete under thermal stresses. For example, the water-cement ratio bears a fixed relationship to the strength of concrete.

In addition, prestressed concrete is of a higher strength than that normally used in reinforced concrete construction; however, there is a greater tendency for prestressed concrete to spall in fire. The mixed proportions of ingredients in concrete can also vary but are usually regulated by A.S.T.M. standard test methods.

Concrete can be finished in a variety of ways that range from a rough porous surface to an almost completely waterproof, glazed surface. Each of the principle ingredients of concrete-cement, aggregate, and water, is indispensable in making concrete; but each can also negatively affect properties of concrete.

Spalling is the fragmentation or chipping away of concrete. In the first part of this article, I discussed the structure and characteristics of concrete including cement, aggregate variations, water-cement ratio, pre-stressed versus reinforced concrete, and concrete finishing.

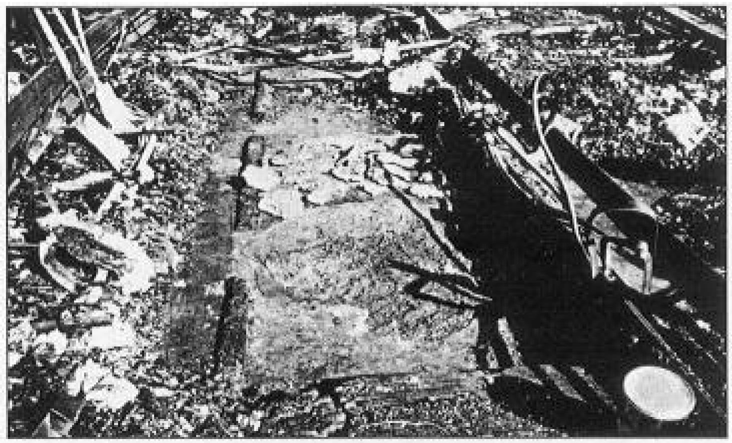
The type of aggregate used in concrete plays a major role when concrete is exposed to high temperatures, but it is not the only factor in determining the behavior of concrete under thermal stresses.

I stated that aggregates play a major role in the behavior of concrete under thermal stresses. In a fire, any material present is subjected to a thermal gradient. That is, the outer surface heats first and continues to increase in temperature as the interior begins to heat. The external layers tend to remain hotter than inner layers thus, maintaining the thermal distribution during the combustion process.

The effect of this temperature gradient on concrete is that the outer hot layers tend to separate and spall from the cooler inner layers. The crumbling or chipping away of the concrete is affected to a degree by the heat conductivity and resulting expansion of the aggregates as they affect the temperature gradient of the concrete. It is easy to see that variations in the thermal conductivity of aggregates will produce radical differences in temperature and stresses which in turn could cause spalling.

Although aggregate composition is the major contributor to stresses set up by steep thermal gradients, some of the most dramatic examples of spalling are thought to be caused by entrapped moisture at very high temperatures. Trapped water within concrete can easily reach a boiling point during a fire and result in steam expansion to 1700 times its original volume. There is a direct link between moisture and concrete and spalling.

I have described two major causes of spalling. We now come to the question critical to the Fire Investigator – Can liquid accelerants cause spalling? Flammable liquids unquestionably burn at a higher temperature than do the contents of most buildings. As I discussed in a previous article, however, it must be remembered that solids and liquids do not burn in those states but must be converted to a vapor or gas before they will ignite or burn. Thus, a cooling layer of liquid (which has given up heat to the vapor above) remains between the burning gas and the concrete until the moment at which all the accelerant has been consumed.



Trapped water within concrete can easily reach boiling point during a fire and result in steam expansion to 1700 times its original volume. Flammable liquids unquestionably burn at higher temperatures than do the contents of most buildings. Copious amounts of gasoline were found at this fire scene.

The temperature of the concrete should not increase significantly until the flammable liquid has burned. Accordingly, most spalling probably occurs from radiated heat after the fire is well developed. Most of the present research conducted on spalling does not indicate the presence of spalling when hydrocarbon fuels are burned on concrete slabs, but does indicate spalling with solid fuels, such as wooden crates, etc., on concrete. Unfortunately, because of the many variables contributing to spalling, such small scale fire tests, do not necessarily indicate performance in well involved structural fires.

Spalling by itself does not indicate the use of a liquid hydrocarbon fuel and can by very misleading. If spalling has a pattern, and if there is an unusual, higher thermal dynamic activity than indicated by the normal fire pressure, then the spalling should be considered a possible indicator of arson. The Investigator should be very cautious, however, when considering only spalling as an indicator that an accelerant was used.

In the case **The State of Alabama-Judicial Department, The Supreme Court of Alabama, October Term, 1988-89, United Services Automobile Association v. Larry Wade and Tracie Wade, Appeal from Walker Circuit Court (CV-85-87)**, an Investigator based his opinion that there was arson largely on a "spalling trail" that he found leading from the basement door toward the center of the room. In his investigation the Investigator failed to clear the entire basement floor of debris.

This investigator is using calcium carbonate to draw accelerates from the concrete. Diatomaceous earth, a product used in swimming pool filters, is also an excellent substance that can be used to extract accelerates from concrete. Flour should be avoided since it can ferment and create alcohol.

Another Investigator called in by the defendant cleared the entire floor and discovered that spalling was prevalent over the entire floor, and there was no discernable "trail."

I will not go into the entire case but highly recommend that all Fire Investigators who want to enhance their professional ability review the case thoroughly. In any event, USAA's Investigator, by removing debris only from one area and hinging his entire determination on the presence of spalling alone, was exposed to the ultimate ridicule of the Court.

If spalling has a pattern, and if there is unusual, higher thermal dynamic activity than indicated by the normal fire load, then spalling should be considered a possible indicator of arson.

Even though considerably more research needs to be conducted, there is no scientific evidence at this point to support the argument that spalling is caused by liquid hydrocarbon fuel.

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