THE MATERIAL IMPACT OF MATERIALS

Nicholas Biery, Ph.D., P.E. S-E-A, Ltd.

At the heart of nearly every insurance loss or legal dispute, large or small, is a failure of some kind. Sometimes the failure is human, the result of one or more decisions that lead directly to the loss. Other times, the failures are literal, and result from decisions made prior to the loss. They can be failures to use an item or part correctly, failures to install a part correctly, failures to manufacture them correctly, or even failures to design them correctly. On the other hand, it could be that the component is perfectly suited for its intended purpose, but it has been used for another purpose for which it is not well suited. Oftentimes, a failure is a literal one, and parts of a system are broken, bent, cracked or degraded so that their intended function can no longer be fulfilled. In these cases, materials science is a tool that may shed light on the cause.

Materials science is a discipline which sometimes seems mysterious, with a specialized jargon that consists of common words applied to new concepts, such as "grain boundary," "dislocation," "band gap," or "inclusion" (which have nothing to do with wheat, shoulder injuries, missing musicians, or social harmony), and unique words like "eutectic" or "martensite." The language is specialized enough that even other engineers often think that their materials brethren, the metallurgists, ceramists, and polymer scientists, are speaking a different language. Ask a materials scientist or materials engineer why your tile counter top cracked when you put a hot pan on it and you're likely to get a long explanation involving sintering, voids, and their impact on thermal conductivity. Ask why a rope failed

and you might get a discussion of common antioxidants and anti-UV agents in plastic fibers. But such obscure knowledge can be of great use when it comes to understanding the cause of a failure.

Materials science can be summarized in many ways, but one (relatively) simple definition is that it is the study of the relationship between the structure and composition of materials and the resulting properties and performance. It also encompasses the methods used to impart or modify the structure and thus the properties, the art and science of turning raw ingredients into the useful metals, plastics, and other engineering materials that are used throughout our modern world. It is the study of how and why things are put together, from the atoms in them to the glue or welds used for final assembly.

This is not to say that the materials scientist is the ultimate expert, able to address every aspect of every case where something is broken, bent, cracked or degraded. There are times where the cause of failure is clear and unambiguous, and there are times where understanding the failure mechanism is a small aspect of a large case. Caution is necessary, however. Without understanding the why and how of a failure, it is possible (and unfortunately quite common) that a component that failed as a result of an incident is interpreted as a cause. An example is a broken bolt in a motorcycle steering mechanism. The injured driver is quite likely to attribute his accident to the failure of the bolt. A materials scientist can tell you by looking at the fracture whether it was caused by years of cyclic stresses, or by hitting an obstacle at high speed. Testing may reveal whether or not it met the manufacturer's specifications for performance. Armed with this knowledge, liability may be directed at the designer, the manufacturer, the supplier, or the user. Similar questions arise in many accidents, where the failure mode of a component, and an investigation of its properties, can determine whether it was the cause of the accident or a casualty.

Materials experts spend much of their time using microscopes, studying the fine details of fractured and broken things, using specialized tests to determine what was used to make them and how, and if there might have been some unfortunate additions to or omissions from the recipe. Established scientific methodologies enable the materials expert to examine a failed rope and determine whether the fibers were cut or broke under tension, whether it was abraded or failed due to a chemical exposure. Laboratory testing can determine the type of fiber used in the rope, as well as give an indication of how weathered it is. The same is true of broken pipes and broken welds, collapsed towers and leaking vessels – a study of the failure can tell us what caused it and oftentimes when it occurred. Testing may also indicate if the fractured component was made properly or not. If a steam pipe splits along a seam weld, a study of the fracture can determine whether it failed because it was improperly made, because it was over-pressured, or because it was exposed to a chemical that degraded it. It may also reveal if a defect in the weld should have been detected during the manufacturer's inspection, or if it started out too small to see and grew in the field. Similarly, through appropriate testing, a materials expert may be able to ascertain if a plastic fitting fractured due to a chemical exposure or due to improper installation, whether a stainless steel connector in a fuel system failed due to the use of off-spec steel or exposure to road salt.

In addition to the straightforward analysis of failed parts, materials science also comes in handy when investigating the more unusual cases. Why is the paint on this house peeling while the paint on the neighboring house is fine? Is it because there is a problem with the paint, or because it was washed with the wrong cleaner? Why do we see cracking in this lot of hose connectors when we didn't see it in the last, even though both meet the material specifications? Was it because they were made incorrectly, or were they exposed to something during shipping? Why is this shipment of silver plated picture frames turning purple, when the last one was fine? Is it the lacquer used to seal the plating, or the omission of a rhodium layer on top of the silver? Questions such as these often are not asked, yet can easily be answered by materials experts. And the answers can have significant dollar amounts tied to them.

So how do you know that you need a materials expert in your case? It would be easy (and self-serving) to imply that you always need one if something is broken, bent cracked or degraded (corroded), but there will be times when you may not. If you have a materials expert you trust, it is certainly worth a few minutes of your time to ask them what they can tell you, to discuss how and why it might be important for your case. If not, you can ask yourself a few questions to get pointed in the right direction.

If understanding the why, how, and when of a failure would enable you to validate one theory of the case and invalidate others, then you should call a materials expert. Their expertise could be the key to your case; engaging the materials expert as early as feasible is best to ensure that the evidence is preserved properly and that the right testing is done. If it is already well known that a part was grossly corroded, leaking, and marked for replacement, you may not need a materials expert to tell you why it failed. Alternatively, you may want one to help you determine if the system designer, the system maintainer or another party is liable for the corrosion. If your mechanical engineer tells you that the loads were several times the strength of the material, you probably don't need to know the details, and likely don't need your materials expert to confirm that the fractured part was overloaded.

When should you avoid calling a materials expert? The easy answer is never since everything is made from a material; if a product has failed in any fashion it is usually a materials issue. However, there may be other engineering aspects to the failure that need to be considered. A reliable materials scientist or engineer will direct you to that discipline. Since materials are such a pervasive aspect of our world and because the materials discipline touches so many of the other engineering disciplines, a good place to start your inquiry is with a materials scientist or engineer. If you have a materials expert whom you trust, you should feel confident that they will direct you elsewhere if they cannot help you. There are cases, however, where you may want to call another expert first. If the system is complex, then the first engineer you talk to should understand the system – if it's a mechanical issue or involves piping, speak with a mechanical or chemical engineer; if it's a building, talk to a structural engineer; if it's an electrical system, talk to an electrical engineer. Of course, there are materials experts who are going to know each of these systems, but not every materials engineer is going to understand every system. Once you hire an expert who understands the system, they will be able to advise if and when it is time to bring in a materials expert.

Dr. Nicholas Biery earned degrees in Materials Science & Engineering from the University of Tennessee (BS) and Carnegie Mellon University (MS and PhD). After school, he joined the ExxonMobil Upstream Research Company where he worked for seven years on cryogenic steels, high-strength pipelines, and other projects. Since joining S-E-A, Ltd. in 2008, he conducts failure analyses and testing for metal, composite, ceramic, and plastic components.