MATERIAL FAILURES

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I. INTRODUCTION

Many losses involve, in one form or another, material failures. In some cases, the material at issue causes the loss. In other cases, the subject material contributes to the size or severity of the loss. In either event, material failures represent an opportunity, albeit sometimes overlooked, for subrogation recovery.

Also, now more than ever it is important to ensure that you have the right expert for the job in proving your subrogation case. Increasingly, defendants are relying on Daubert to exclude experts and dismiss claims. Gone are the days when you might rely solely on an electrical engineer to prove a product defect or a mechanical engineer to prove a mechanical failure. Oftentimes, losses require the collaboration between mechanical, civil and electrical engineers and a materials scientist. Many losses such as mechanical failures require the collaboration of a mechanical engineer and materials scientist to prove the failure. Likewise, a product liability case may require the collaboration of an electrical engineer and materials scientist to prove the exact product defect.

Knowing what a materials scientist is and how he or she may assist in proving your claim are important steps in the process of determining if subrogation is viable and assisting us in maximizing the recovery for the client.

II. TYPES OF MATERIAL FAILURES

There are many different types of material failures that arise in the context of losses which can lead to viable avenues of subrogation recovery. The most common of these involve

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plastic and metal. These materials are commonly used in a wide variety of everyday applications. It, therefore, should not be surprising that these materials play a large part in the occurrence of losses, either by virtue of causing the loss or by making the loss worse than it otherwise might have been. Recognizing and understanding the role that materials play in a given loss will help in identifying all potential and viable avenues of subrogation recovery.

With respect to plastics, this material dominates our everyday lives. For example, plastics are used to make the appliances in our homes, plumbing fixtures, as insulation on electrical lines and fixtures, and as packaging material for food we eat. With respect to metals, this material continues to be widely used in many applications that we use and see everyday. By way of example, metals are used as the conductors for electrical lines, as windings for motors, as structural supports for buildings and, in the case of pre-engineered metal buildings, as the primary material for the buildings themselves.

Knowing that materials are out there is fine, but understanding what role, if any, they play in a particular loss can potentially open up new avenues of subrogation recovery. For example, it is more and more common for plumbing fixtures to be made out of plastic. Plastic is far less expensive than metal and can last as long, or longer, if properly manufactured and installed. However, problems can and do arise when this does not occur. Plastic plumbing components can be over tightened by the installer leading to hairline fractures of the material that do not manifest themselves as a full scale failure until many months or years later. In addition, improper choice of the particular type of plastic by the manufacturer or improper casting of the plastic could cause the plastic to fail under what otherwise would be normal and anticipated usage. It is important to recognize these possibilities and to hire the appropriate materials expert to investigate and determine the specific cause of the failures so that their role in causing the loss, if any, can be assessed.
Given their wide variety of usage, plastics may also play a role in the spread of fires, even where the cause of the fire is unrelated to the plastic. In its pure form, plastic is highly flammable. Plastic is, after all, a hydrocarbon and, as such, will readily burn. If a flame is applied to it, it will sustain and spread the flame. Depending upon the type of plastic and its intended use, manufacturers can place various kinds of “fillers” in the plastic to reduce its ability to sustain or spread flame. In the past, a commonly used filler was asbestos. Asbestos actually gives off water vapor when it burns which helps to extinguish a fire. Today, a commonly used filler is limestone. Limestone absorbs heat and gives off a gas as it burns, carbon dioxide, which also helps to extinguish a fire.

Depending upon its particular composition, plastics in large quantities can play an important role in increasing the severity and duration of a fire. For example, plastics may be stored in large quantities in warehouses to be used later to produce or package goods. In addition, plastics are commonly used today in shopping carts. Although individual carts may not present a significant risk of contributing to the spread of a fire, multiple carts stored together in accordion fashion can present a sizeable fire load capable of substantially increasing the size and severity of a fire. In assessing the aftermath of any fire involving large amounts of plastic, consideration should therefore be given to whether the plastic played any role in making the fire damages worse than they should have been. Specifically, the plastic itself should be examined by the appropriate expert to determine whether its composition unnecessarily contributed to the spread of the fire. In addition, the appropriate experts should be consulted as to whether the existing fire suppression system, if any, was appropriate given the fire load presented by the plastic.

Metals are commonly used as building materials, either alone or in conjunction with wood products. Roof failures, which occur with some frequency in northern climates as a result
of snowfalls typically implicate the role of metal structural supporting members or entire pre-engineered buildings. Almost without exception, the response by the architect, engineer or metal building manufacturer to claims involving roof failures is that the snow load far exceeded any reasonably anticipated amount and therefore these parties should not be responsible for the loss (the “Act of God” defense). This, of course, might be true in some cases. However, it is important to determine what the design load capacity of the materials/structure was versus what it should have been at the time of the loss. Notwithstanding the presence of heavy snows, it may well be that the material and/or structure was under-designed by industry standards or codes and should have withstanded the actual snow load however large it may have seemed. It is important to retain the correct materials expert to examine and document the failed building components immediately following the loss and to gather the necessary information to determine whether the materials/structure was or was not deficient.

Metals can also be the cause of fires. For example, the windings of a motor or the copper conductor of any electrical wire can overheat and short circuit for a variety of reasons. The “arc” or “spark” given off by the failure of the metal can reach temperatures as high as several thousand degrees Fahrenheit, easily high enough to ignite ordinary combustible materials if located nearby. Prompt investigation, documentation and, if possible, preservation of the remaining evidence may be essential in determining the cause and, if appropriate, assessing third-party responsibility. Metal conductors and windings can typically leave certain “telltale” signs which are indicative of it being the cause, rather than the victim, of a fire. It is important to promptly get appropriate materials and/or electrical experts involved to analyze the evidence and to assist in that determination.

In short, in considering any loss, thought should be given to the role, if any, that materials may have played. Even in cases where a particular material may not have anything to do with
the initial cause of the loss, the presence of material may well have served to make the loss worse than it otherwise should have been. It is important to act promptly to document and preserve the material evidence and in retaining the appropriate material experts to analyze and determine the role played by the material in the loss. Failing to recognize the role that a material may have played in a loss is simply and unnecessarily forfeiting a potential avenue of subrogation recovery.

III. **WHO IS A MATERIALS SCIENTIST AND WHAT IS HIS/HER EXPERTISE?**

A materials scientist is a person having a fundamental knowledge of a broad base of materials. He/she can have a degree in metallurgical engineering, ceramic engineering, polymer science or material science. However, because of an increased use of polymers (plastics) and other high tech materials, engineers with specialized degrees have had to become “materials engineers” through additional training and experience.

A materials scientist will have a fundamental knowledge of the properties, the manufacturing techniques, the physical and mechanical responses of materials such as metal, plastic, rubber, ceramic and glass. He/she will not only understand the capabilities of these materials, but will have knowledge of their limitations. The material scientist will have the capability and the tools to examine fractured, broken or damaged materials and be able to determine the root cause of failures.

**Tools of the Trade**

Materials scientists use tools that are typically unique to the materials engineering laboratory such as chemical analysis tools, hardness testers, stereo microscopes, metallographs and scanning electron microscopes (SEM). The use of an SEM can be a pivotal step in a failure analysis. The SEM allows the materials engineer to view fracture surfaces at extremely high magnifications (5000X). It uses electrons instead of visible light radiation to create an electronic
image or picture (much like a television camera) of the fracture surface. This allows examination at a very large depth of field that would be impossible for a light microscope. Using the SEM allows investigators to reach conclusions about: (1) the direction of force that caused a failure, (2) if the failure was by overload (too much load) or by some other mechanism such as (3) fatigue (repeated or cyclic loading), (4) corrosion, (5) environmentally assisted cracking, (6) creep (gradual deformation at constant load) or (7) caused by small internal defect such as “seeds” in glass, “bubbles” in plastic, “porosity” or “inclusions” in metal.

The SEM not only allows high magnification examination of the fracture surface but it can be equipped with an attachment known as an energy dispersive x-ray spectroscopic analyzer (EDS). The EDS allows semi-quantitative chemical analysis of a small spot (0.00001” in diameter) on a surface. This can help identify impurities or foreign objects and can help determine corrosion species.

**When is a Materials Scientist Needed?**

It may not always be apparent at the beginning of a new loss that a materials scientist is needed. Even engineers sometimes cannot evaluate the proper discipline required to determine a failure until after an initial inspection. In a large percentage of failures, either a mechanical or electrical engineer and a materials scientist (or metallurgist) are required to conduct a complete analysis of the failure. Fortunately, because a materials scientist’s usual focus will be on a particular item, e.g., a broken pipe, the contacts of a toaster, a gas valve, a screw, and these items likely will be secured from the loss site, these items can be evaluated by a materials scientist at a later date. While it is always a good idea to involve any necessary experts as soon as possible, do not despair if you do not involve a materials scientist at the beginning of a loss as chances are he/she can inspect the pertinent evidence later and still be of great assistance in proving your case.
Examples of Where a Materials Scientist May Be Helpful in Proving a Case

Mechanical Failures

A mechanical failure is defined here to be the failure of a machine or structure to operate properly because of a broken, bent, abraded or corroded component. The failure can simply result in the inability of the machine to function or can lead to additional damage or even injury. The root cause of the failure is generally one of three basic aspects of engineering systems and components, (1) proper design, (2) proper maintenance and (3) proper operation. A thorough evaluation of mechanical failures often involves an interdisciplinary approach.

All engineering disciplines overlap with other engineering fields in some areas. For example, mechanical engineers must understand the principles of fluid flow to analyze hydraulic systems. This field of study is similar to water flow that civil engineers use and air flow that aeronautical engineers use. There are also areas of science that are almost unique to one engineering discipline. For example, vibration and steam pressure thermodynamics are primarily addressed in mechanical engineering while corrosion is a focus of metallurgical or materials engineers primarily. Many failures involve more than one engineering aspect and, therefore, can require more than one engineering discipline to address the failure adequately.

The general areas of expertise of mechanical engineers include vibration, air conditioning and heat pump cycles, ventilation, combustion engine, hydraulics of both liquid and gas, mechanical component dynamics, structural and machine component design. An analysis of a failure may include several of these areas. For mechanical failures, the mechanical engineer addresses primarily three aspects of the machine or component; (1) was the part adequately designed by the manufacturer to transfer or support the intended load (is it strong enough), (2) were proper maintenance recommendations made by the manufacture and followed by the owner and (3) was the part abused and did the manufacturer warn against foreseeable abuse.
In conducting a failure analysis, the mechanical engineer may find some evidence of abuse such as a dent that is not explained by the failure. The engineer may also find fractures that are not explained by a design analysis. A paper or mathematical analysis may simply be insufficient to explain fully the cause of a failure and for these cases a physical analysis of some aspect of the failure must be undertaken. This could include, for example, a detailed inspection of the fracture surface or a microscopic examination of particles in lubricating oil. Mechanical engineers usually are not equipped or experienced to perform these tasks. These tasks require the expertise of a metallurgist or materials scientist.

A materials scientist is trained in areas of materials manufacture and utilization. They are involved in determining and improving the physical and mechanical properties of materials. This aspect of materials engineering overlaps with mechanical engineering because the materials scientist must understand design requirements in order to improve the performance of materials. The materials scientist also studies and evaluates failures to understand the fracture process and has experience in examining fracture surfaces. A materials scientist can “read” the appearance of a fracture and determine the cause of failure. Such materials that can be analyzed include metals, plastics (polymers), rubber (elastomers), glass, and ceramics. Sometimes a mechanical engineer can analyze a failure only so far. A materials scientist may be just the person you need to find the last piece of the puzzle to prove your claim.

**Water Losses**

**(a) Pipe Bursts**

Perhaps one of the most common property loss sources is water damage caused by a pipe or hose burst. Analysis of a pipe burst often starts with a mechanical engineer conducting an evaluation of the flow of water and hydraulic calculations. In some cases the analysis can not explain why the pipe broke. That is, the pressure was not sufficient to cause a fracture of the
pipe. One example is a case that involved the bursting of a sprinkler system. In that case, the mechanical engineer suspected that the water in the pipe had frozen, but the pipe also could have contained a defect that caused it to fail below the rated pressure of the pipe. In order to determine the exact cause of the burst, it was necessary for a metallurgist to conduct a detailed examination of the pipe to determine if any defects were present or if the pipe failed simply due to overpressure.

The metallurgist’s examination revealed that there were no material defects and, therefore, confirmed that the pipe must have failed due to overpressure. The only way that the pipe could have been overpressured was for ice to form inside the pipe. The materials scientist’s findings placed liability for the flooding squarely on the sprinkler system designer who had not required sufficient insulation around the pipe, which, in turn, allowed ice to form in the pipes and caused them to burst. Without the materials scientist, the mechanical engineer’s opinion as to the cause of the burst could have been deemed speculative and possibly excluded under Daubert.

(b) Material Failures of Plastic Plumbing Fixtures

There are many subrogation opportunities relating to water losses arising from material failures of plastic plumbing fixtures and piping. Materials scientists are especially instrumental in determining the causes of these types of failures because oftentimes, a degradation of the fixture material or an over-tightening of a fixture, both of which can be determined by a materials scientist, causes these losses.

Generally, plumbing fixture losses are caused by poor product design, inadequate testing and/or improper installation. Increasingly, manufacturers are making plumbing fixtures out of polymers (plastics) which are not compatible with the chemicals found in most water supplies. The interaction between the polymer and chemicals can lead to degradation, stress fractures and cracking. A materials scientist can be very helpful in determining the type of material out of
which the fixture is made, whether a chemical attacked that material and whether that attack caused or contributed to the loss.

(i) Stress Corrosion Failures and Incompatibility with Water Supplies

Some of the plastics used to make plumbing fixtures that are not compatible with various chemicals found in potable water supplies include polyethylene, polypropylene, and polybutylene. Acetal is another polymer, which is known to be incompatible with chlorine and other oxidizing chemicals.

One common source of failures in plastic plumbing components is environmental stress cracking in the plastics. Environmental stress cracking in these types of plastics has been known for approximately two decades. In 1981, R. A. Bruback of Dow Chemical published a paper in Polymer Magazine detailing the kinetics of environmental stress cracking in high-density propylene. Environmental stress cracking, otherwise known as ESC, can occur when the plastic is notched, or somehow damaged during installation. Another form of ESC involves a dry pore/craze structure that is formed under stress. Either one of these integrity failures can allow an outside agent to enter the material. The outside agent can be something as innocuous as water. However, it is extremely rare for plastic plumbing fixtures and components to come in contact with pure water. On the contrary, public water supplies contain chemical treatments to purify the water. Even low concentrations of these chemicals can accelerate this deterioration.

One such chemical is chlorine. Public water supplies commonly use chlorine as a disinfectant. This is added before it leaves the water treatment facilities. High levels are added at the facility because such levels are expected to diminish as the water reaches the consumer. Therefore, high levels can be found closer to the facility. Another common chemical, which can accelerate the degradation of plastics, is ferric chloride, which is used as a coagulant. Ferric chloride is used during water treatment, but traces of this substance also come through to the
final end-user of the product. In addition, galvanized piping and brass plumbing components can be sources of zinc. Zinc can combine with naturally occurring chlorides to form zinc chloride, which can also damage plastic plumbing fixtures and piping.

All of these chemicals commonly found in public water supplies can greatly accelerate the deterioration of plastics. In addition, the environment of the plastic component is often one containing soaps, detergents, oils, or liquid bleaches. These aggressive agents, known as oxidants, can also be a source of chlorine and can appreciably reduce the stress at which cracks will form. Therefore, environmental stress cracking in plastics is a common failure, and should be accounted for by the manufacturer in the design of the product. If the manufacturer has performed inadequate testing on the components, then the manufacturer is liable under product liability theories.

One common cause of environmental stress cracking is a combination of over-tightening of the fixture coupled with environmental agents which increase the susceptibility of the plastic to stress cracks. For example, a toilet valve is connected to a toilet using a plastic nut, which connects the incoming water line of the piping to the toilet valve. This plastic nut serves to secure the base of the toilet valve to the toilet tank. The consumer often installs these nuts. It may be difficult for the consumer to tighten the nut to the point that leaks will not occur. Therefore, a consumer may over-tighten the nut, which creates extreme stress on the outermost threads of the nut. At this stress point, the pore/craze structure discussed above can occur. When it does, water is allowed to seep into the material and accelerate the stress cracking process. The greater amount of chemical oxidants in the water supply, the more quickly the stress cracking can occur. Eventually, the nut cracks and creates an unexpected leak. If there is no one present to discover the leak, the leak can continue unabated and cause severe damage.
Another example concerns a filter housing which is used to contain chemicals intended to purify the water. Such filter housings typically contain a top piece and then a bottom base screws onto the top piece, and holds the chemical. These housings can be susceptible to environmental stress cracking. If the base of the housing is over-tightened, that creates a stress condition on the threads of the bottom component. In addition, the filter housing, by its design, is intended to hold chemicals, which can greatly accelerate environmental stress cracking. Under these circumstances, it is easy to see how environmental stress cracking can occur, and again, serious damages can occur if leakage occurs and if this leakage occurs which is unnoticed and continues unabated.

The most well known problem arising from the use of plastic plumbing was the Polybutelene Piping litigation. Polybutelene is a form of plastic resin that was used extensively in the manufacture of water supply piping from 1978 until 1995. It was believed to be the “pipe of the future” and is also believed to have been installed in at least 6 million homes. The primary problem with the polybutelene piping pertains to its incompatibility with some water supplies. Specifically, oxidants in public water supplies, such as chlorine, are believed to react with the polybutelene piping and cause them to become brittle. Micro fractures result, and the basic structural integrity of the system is reduced. The piping system then becomes weak and may fail without warning, causing damage to the building. The greater the amount of oxidants in the water, the more likely these failures are to occur.

Another common failure mode that can occur is simple deterioration of the plastic due to hydrolytic degradation. Many plastic plumbing fixtures are made of what is known as “acetyl” plastic. Acetyl plastics deteriorate due to hydrolytic degradation. Put simply, the tensile strength of the plastics is lowered when constantly exposed to water. This deterioration is accelerated by exposure to chemicals in water.
Water losses caused by the failure of plumbing fixtures made of plastics are a fertile ground of subrogation. Manufacturers can open themselves up to liability by failing to conduct adequate testing to determine the affect of waterborne chemicals on plastic plumbing fixtures and/or for failing to discontinue the use of such materials after becoming aware of a problem.

(ii) Stress Concentrations

Other failures of plastic components can occur, regardless of environmental water. These occur primarily where "stress concentrations” occur. A stress concentration occurs when a greater degree of stress is imposed on that portion of the plumbing fixture than is imposed on the remainder of the fixture. Often, the plastic portions of the fixture are not designed to withstand such stress concentrations and the component breaks. There are so many different types of stress concentrations that can occur, it is impossible to deal with such failures in more than general terms. However, in any failure of a plastic plumbing fixture, the fact that the portion of the plumbing fixture that failed might have been “overstressed” must be considered. Often, these losses can result in viable product liability claims against the manufacturer.

(iii) Improper Installation

Lastly, another significant problem that may arise from the use of plastic components for plumbing fixtures and piping is over-tightening or over-torquing. Plumbing components have to be securely tightened during installation to prevent leakage. Plastic components are susceptible to damage if improperly tightened or overly tightened. For example, the tightening of the plastic nut at the inlet portion of the waterline to a toilet valve can crack if over tightened. Over time, this crack can expand until the nut fails and leakage occurs. A materials scientist can determine whether the failure was caused by overstressing during tightening, some form of trauma, or some form of incompatibility between environmental water and the materials of which the fixture or piping is made. Therefore, for these types of claims, you may wish to retain both a plumbing
expert to investigate the cause of the loss and a materials scientist to determine if over-tightening or fracturing is involved.

**Electrical Fires**

Electrical engineers often analyze fire for origins in electrical equipment. Wood frame house fires do not generate temperatures high enough to melt copper. Thus, when an electrical engineer finds a bead of metal that was molten he/she can conclude that the bead was caused by arcing and probably not caused the fire. This is true if the bead of metal is copper. The temperatures reached in fires are high enough to melt aluminum. Drops of aluminum can fall onto copper forming an alloy of copper and aluminum. Thus, a chemical analysis of the bead must be conducted in order to determine if it is pure copper, pure aluminum or an alloy of copper aluminum. The EDS attachment of an SEM is the perfect tool for such an analysis

**Collapses**

Not all material failure analyses require the use of an SEM, but some may require the coordination of a group of experts. One example is the collapse of a large, 500-foot crane. The failure of a kingpin on a crane required metallurgical analysis of the pin, but a complete failure analysis required civil and mechanical engineers and a civil engineer specializing in wind loading to work together to explain fully the cause for the collapse. A mobile crane of that size required very precise control of the tracking unit remaining level. Deviation from level imparted loads that were not expected.

Thus, a civil engineer was required to determine if the soil conditions were such that the tracks would not sink under the load. The mechanical engineer conducted a detailed stress analysis of the entire structure called finite element analysis (FEA). Because the failure occurred on a windy day (winds were over 10 knots), the influence of the wind load on the skeleton structure of the boom and the beam the crane was lifting had to be conducted by an engineer specializing in that area of civil engineering.
Another example of where a materials scientist was helpful in excluding and/or pinpointing the cause of a collapse involved the collapse of a nine-month-old bowling alley. The building collapsed two hours after a Sunday school bowling party ended and the building was closed. With only about a 6-inch snow load, the main room over the alleys collapsed. The roof trusses or beams in this case failed at the center crest of the roof by fracture of welds. A metallurgist was called in to investigate the failure. His analysis suggested that the welds were sound and of good quality and, therefore, ruled out a materials failure. A civil engineer then analyzed the structure and found that improper connections were used to locate the beams to the foundation thus causing the collapse.

**Conclusion**

As is illustrated above, a materials scientist may play a pivotal role in establishing the cause of a loss and his/her usefulness in proving subrogation claims should not be overlooked. More and more a collaborative effort between several experts may be needed to prove subrogation claims and avoid the pitfalls of Daubert. Whether a product failure, electrical fire or structural collapse, bear in mind that a materials scientist may be just the right expert for you.