BioSpan

PAVEMENT DISTRESSES AND GREEN SOLUTIONS

A Guide to Asphalt Distress and Pavement Preservation Applying Solutions from BioSpan Technologies, Inc.

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Second Edition

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Foreword

A Happy Accident on the Road to PAVEMENT PRESERVATION

We got started by accident. Not BioSpan Technologies—that was intentional—but our pavement solutions product line started with a little mad science. In the early 2000s, I was developing a new sterilization product that would be non-toxic to all vertebrates. I accidentally combined two compounds, supposedly incompatible, and got so excited when they combined without forming a gooey mess that I dropped everything on an asphalt tile floor. With the flask broken on the floor, I watched the asphalt tile dissolve to reveal the foundation below.

As a teenager growing up in Chicago, I earned money for college by patching asphalt pavement for the city and making coal tar at the steel mills. It was back-breaking labor, but thanks to this experience, I had some idea of what reaction took place when I saw the tile dissolve on the laboratory floor.

As serendipity would have it, a county engineer stopped at our office in Washington, Missouri and asked if we had anything that would keep his new distributor clean the same week. I dropped the mystery solution on the asphalt tile floor. And so, AR-3600 Asphalt and Tar Remover was discovered.

The rest is history. The paving industry met the criteria for a good business model: a large market, few competitors, suitable margins and a high barrier to entry. Over the past two and a half decades, I have had the pleasure of working with many of the most professional engineers and paving experts from industry and the departments of transportation, who have asked me to help solve their pavement problems. They are all after one thing: a perpetual paved surface that requires little maintenance and costs next to nothing. It has been a pleasure working with these professionals and developing innovative new "***green***" solutions that make the paving industry safer for people and the environment, and work better than their petroleum-based counterparts.

Thankfully, I haven't had to drop anymore lab equipment at BioSpan to bring our patented solutions to the world. I hope you enjoy reading this book, particularly the educational material from Tom Keith, PE, that follows.

This publication is dedicated to all the pavement professionals that work diligently every single day to make our roads last longer and safe!

Sheldon R. Chesky, Ph.D., MBA
Founder and Chief Scientist, BioSpan Technologies, Inc.

Preserving Asphalt Highways and Related Surfaces

By Thomas E. Keith, PE
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Highway and Pavement Solutions (MODOT)

About the author: Mr. Keith has worked in the highway industry for more than three decades, beginning in roadway, quarry and field inspection for the Missouri Department of Transportation (MoDOT) in a career that has passed through all districts of the state of Missouri and all engineering divisions of MoDOT. Mr. Keith has produced numerous internal papers and external presentations on pavement management, highway materials and other highway related issues, and he has a reputation for writing strong specifications for pavement design. He participates in nationwide groups and task forces in related areas and is a registered professional engineer in Missouri. Mr. Keith holds a BS and MS in Civil Engineering from the University of Missouri – Rolla (now known as Missouri University of Science and Technology), where he authored his thesis and several papers on the use of waste glass obtained from domestic garbage in asphalt mixtures.

Preface

This is intended to educate and expose those new to the highway field, to new terms and ideas, related to their field of selling or implementing highway related products. The author has taken the liberty of keeping the subject simple, while attempting to explain the significance of items felt to be of importance. Memorizing this document will not make you an expert in the industry. But internalizing the content may well enable you to ask intelligent questions of a prospective customer, as well as make connections that might otherwise be obscure.

Good reading to you, and may you always understand the end use of your product. To do otherwise is to limit your sales and livelihood.

- Tom

WHAT IS A HIGHWAY?

What expertise I have in the highway industry is largely thanks to Missouri and MODOT, because of my career there. Thus, what is contained herein is based in that context. And since I love highways and have no axe to grind, the subject matter herein is intended to be unbiased, except as might occur out of my ignorance. That is not to say that there are no statements here that might be construed as opinions. There are. But since I'm the one writing this, consider it the writer's prerogative to explain, not to misdirect. Any statements in error or out of context are made honestly. Point them out, and we'll make corrections.

The nice thing about DOT highway materials is that: a) they are similar from one coast to the other with some exceptions and 2) state DOT organizations are similar for all 50 states, again with some minor exceptions. Thus, by understanding Missouri, one is guided toward understanding highway aspects anywhere else in the US.

When I speak of highways, I mean the structure that carries rubber-tired, petroleum-fueled, combustion-engine vehicles in continuous contact with the surface, loaded with personnel and freight, with the freedom to go in many directions at will. Highways carry more than 80 percent of the nation's goods and probably more of its people. If you understand highways, you understand other forms of transportation, as the remainder are just specialized forms of transportation. There is no other form of transportation that is as flexible, that can provide today's "just-in-time" service to all or that can carry the volume necessary for US commerce other than highways.

The US Interstate highway system was built under the excuse of defense but was designed to get people and goods from Points A to B as efficiently as possible. It succeeded beyond all expectations. The paved highway supports our present economy and lifestyle more efficiently and effectively than any other form of transportation. It is difficult under current conditions to transport your morning freight necessities—a bowl of cereal, a jug of milk and a roll of toilet paper—to your house any other way than by truck.

What will our next transportation system look like? It must be energy conservative and flexible in use. It will be a friend to gravity (close to the ground) and have minimal friction on a smooth surface. It will have tremendous capacity, will combine, or split into as many load segments as necessary and go in any direction desired, at the whim of the operator. Except for this last point, rails or pipe transportation might win—but taken together, it sounds like a form of freight highway to me. Other talk is foolish and futile.

Let's go another layer deep and talk about the materials. Soil, concrete mix, steel, aggregate, bitumen, cement, asphalt mix, air entrainment, mix design, pavement design: this is the stuff that highways are made from. The material is not so different from the material the Romans used to construct roads and buildings 2,000 years ago, some of which still survive today. Those materials and processes are what I will discuss in this guide, after we get some overhead out of the way.

DOT SYSTEMS

Most highway systems are controlled by some form of authority. Early in the US development, there was a sense of governmental obligation to do things for the general good and welfare of all, despite the protests of a minority. One must wonder at the present-day wisdom of finding the lowest common denominator that satisfies all!

One of the governmental obligations assumed was the establishment of road authorities, the model of which exists at all levels of government today, whether it be city, county, state or federal. The current pet phrase is Department of Transportation, or DOT, which also now includes oversight of other forms of transportation. Not long ago, many were called Highway Departments.

Most DOT organizations are guided by the federal DOT. Its rules, guidelines and specifications become those of lesser DOTs, from the state down through county and city, even to a local gravel road. The rules of conduct are similar as a result, and that allows us to make some common observations about DOTs.

Business Methods: Most DOTs do business by "low bid," where the supplier with the lowest price wins. Why? In the early days of big transportation in the late 1950s—days of large projects and big money—several national investigations revealed that a lot of money was being wasted by government officials. Nepotism, cronyism, kickbacks, and other questionable practices uncovered in the investigations prompted a new standard focused on the lowest bid.

While private business owners have greater flexibility because wins and losses are maintained in a private entity, in government, officials are responsible to the taxpayers. The fairest way to conduct business is to fully describe your project using specifications—how big, long, deep, what color, how wide, what properties, what materials and so on—and gather bids for that work. The contractor offering the lowest bid gets the work and is required to construct it in strict accordance with the specifications, with no contract alterations. This is how we got into low bids.

While there are legal perversions of the low bid approach today, properly enforced low bid procurement is the fairest way of doing unbiased business and getting the lowest price. It's tough on contractors and suppliers, as it offers little sympathy for errors. The other downside of low bid procurement is that often the finished product barely meets specifications as described, and there is no leeway for contractors to go one step higher for optimal performance.

So, you had better have good specifications. A few governmental agencies are allowing their purchasing agents to use some latitude to procure best-value products, but this is subjective, so most agencies tend to follow the low bid model.

For that, you must have the lowest cost product that closely meets the specifications. You may find room to sell a more appropriate or longer-lived product for slightly more money on some opportunities. Here, you'll not only have to sell a product on its merits, but also keep out competition and leave the door open for repeat business. For those with a unique product and an open door, opportunity emerges. But the same low bid guidelines often require competition to ascertain a fair bid or point of comparison, and you might find a unique product cannot be included in your bid.

Specifications: While there are federal DOT specifications, most highway material specifications come from the state DOT level in the form of those created by ASTM and the American Association of State Highway Transportation Officials (AASHTO). And while there is some variation from state to state, often the same specification is used for many projects. State DOTs become the model for county and city DOTs, which often use the same specification as states without understanding the specification might not be applicable at a county or city level, or that enforcement is required to make the specification worthwhile. As a result, at the county or city level, you might find yourself bidding on the wrong products or applications against low-quality competition. Understanding the requirement and end use is key to a successful argument for a more appropriate product or keeping your product away from incorrect or even harmful use.

When submitting a bid to a government entity, you must understand the following:

- What is the desired result?
- Which specifications are in force, and what is the method of enforcement?
- How do you argue that your product is more applicable than the competition's?

Arguing that your product is better after the bid in a controlled, low-bid situation based on a specification is useless. It is better to sell your product and make your argument for specification improvement next time, if warranted, so you can provide the appropriate product in the next bid.

Always be available to assist in honest specification development. Not only are you able to gauge your product applicability by learning what is needed or developing ideas for new products, but with a good product you can also improve the quality of the specification, which makes winners out of both of you. And everybody likes a winner!

ROCKS AND SOILS

With apologies to my soils and geology friends for the simplicity, it all starts here: in the ground, dirt and muck—the soil. In fact, if it is not soil, it is rock. There are other variations in between, but by talking of soil and rock, we can cover a lot of ground.

To keep it even simpler, we can just discuss rock. After all, rock is the origin of all soils. When the molten center of the earth becomes exposed, cools, and hardens, the net result is *igneous rock*. Rock also can be formed by applying pressure to a gathering of solid material. For example, coal is formed by high pressure applied to organic materials over the eons.

In the same way, *sedimentary rock* formed as fossils, salts and other sedimentation sank to the bottom of the seabed and became cemented together as pressure was applied over time. In Missouri, sedimentary rock takes the form of limestone, or dolomite. If you continue to apply pressure to limestone, you achieve marble, like the Carthage marble mined in southwest Missouri.

If you were to slice off a chunk of Missouri and examine the side, much as you would cut away a slice of cake, deep down you would find molten magma like that which oozes out of volcanoes. Closer to the surface, you would find solidified magma, or igneous rock. And on top of much of the igneous rock, you would find layers of sedimentary materials formed over the eons by ancient seas. Layers of limestone, dolomite, coal, and shale (a mixture of limestone, organics and other sediments) exist hundreds of feet deep. In fact, in Missouri, there are only a few places where the igneous rock comes to the surface, such as south of St. Louis. There, you will find igneous rock termed *traprock* or *porphyry*, which is surface mined for its iron content and used for roadbuilding. MoDOT uses it for special, friction-resistant surfaces due to its hard, angular characteristics. Transportation costs prohibit movement of large quantities of traprock, except for special projects.

Otherwise, if you dig into the ground in Missouri, you will find sedimentary rock. And that is where the bulk of the state's construction materials come from: surface mines. Because of the ready access to surface-exposed rock, there is no need to dig the deep mines associated with coal or other precious metals. As a side note, there are a few deeper mines now being developed. A couple in Kansas City are 600 to 800 feet deep, one actively mining to select limestone desired for cement making. Curiously, as the sedimentary layers become tilted and warped as the earth's surface deforms over time, what is mined 800 feet deep in Kansas City is exposed at surface-level in the Marshall Junction area to the east.
In fact, this *sedimentary tilt* provides Missouri with a unique spectrum of exposed sedimentary rock. If you start at St. Joseph and move in a straight line toward the exposed igneous material south of St. Louis, you'd find yourself looking at older and older sedimentary rock on the ground as you moved southeast. The younger rock in the northwest is thin bedded (one to 20 feet) and generally lower quality. In the older layers to the southeast, you find thicker bedding (some exceeding hundreds of feet) and higher quality formations. At the bottom of the sedimentation, south of St. Louis, you find the solid igneous rock supporting it all. And if you stopped in your travel at Marshall Junction and looked to the northeast and southwest, you'd find the same rock formations exposed along a line running at a right angle to the one you're traveling. Thus, the Warsaw formation mined in Joplin is also exposed toward Hannibal. And if you are mining Bethany Falls formation rock in Kansas City, do not bother to look for it in Jefferson City. It does not exist. But you will find the Callaway formation, which is exposed west of Jefferson City, in the Kansas City mine, if you dig deep enough.

Kansas City is unique in that there is a shallow limestone rock formation there called Bethany Falls, which is usable as road aggregate and one of the thicker formations in that group. It is uniformly 15 to 20-feet thick, flat (i.e., parallel to the surface) and close to the surface (zero to 50+ feet of overburden). One can mine the bottom portion and support the top portion as a roof by leaving pillars, forming *room mining*. This was done for years, avoiding the expense of removing overburden and leaving 10 to 15-feet tall rooms under the surface. The cold storage and office industry found that underground storage ideal in terms of protection, low maintenance and low utilities, and now claims it as premium space. In fact, mining for rooms has become a business, with aggregate production becoming secondary. There are a few areas of the state that have some minor work like that, but Kansas City is unique with the combination of a) a usable formation, b) a formation so uniform and flat, and c) an urban demand for space above and below the ground. Most of the Worlds of Fun amusement park resides on top of underground office and storage space.

This is the long way of saying that the combination of igneous and limestone rock gives Missouri unique geological properties, which ultimately affects the state's highway construction.

It was noted earlier that there is a relationship between soil and rock. Soil is simply rock that has been worn away by water, air or mechanical abrasion. If it is on top of the surface, we mix in a little organic matter—leaves, sticks, bugs and so on— and call it *topsoil*. Topsoil is not good for building roads because organic matter decays over time, making the soil unstable. So, what to look for is under the topsoil.

Soil may vary from that containing only extremely fine particles (clays) to that containing larger, visible particles of rock (gravely, rocky soils). Roadbeds are of lesser quality when built out of clay and other soils, as opposed to lots of rock. The soil is influenced not only by the parent rock and the organic matter in it, but also by how it got to where it is, usually water or air transportation. Just as Missouri has characteristic rock formations in each area, the state also has specific soil layers in different areas. Let's back up and look at how the current soil got where they are.
As rock is exposed, it weathers and is broken down by air and water. Those forces may transport it great distances from its origin. Tens of thousands of years ago, while the exposed sedimentary rocks were weathering, glaciers came down from the north, pushing into Missouri. The Missouri River used to be in north central Missouri. Glacial action shoved it southwest to its current location. Glaciers are tremendous earth and rock movers. As they moved south, they carried ground-up rock from the north and amassed even more of it as they migrated. Later, as the glaciers receded, they left a gentle rolling terrain with clay lenses, sand and gravel deposits and deep soil from the material carried by the meltwater. That is why today, land north of the Missouri River is rolling terrain. Historically, glacial gravel deposits have been mined in the Hannibal-LaGrange area and other northern Missouri locations, which contain materials from further north. There are fewer surface rock mines in north Missouri because the rock was chiseled away by glacier movement and covered with deep soil.

South of the river, we find the Ozarks: hills and shallow soils weathered in place, and lots of exposed bedrock, except for southeast Missouri. As you go down I-55 into southeast Missouri, you trade the hills for the lowlands. If you look west, you will see a visible hill line called Crowley's Ridge, which runs into Arkansas and marks the change from hills to lowlands. The ridge is a shoreline formed eons ago by a lake that existed in southeast Missouri. In it, you will find clay and gravel, a natural mix mined and used for road material for years. The soil in southeast Missouri tends to be bottom-of-lake soil like clays and gumbos, which are even worse than the soil from north Missouri for road work, but they do grow lots of rice!

Commonly found along the hills of the Missouri River, a windblown soil called *loessial soil* or "sugar soil" can be found. It is predominantly a one-sized particle soil, stacked up and lightly cemented together over time, much like damp sugar. It can be cut and will stand best with a vertical face. However, water cuts and erodes it. There are exposed faces of it in Kansas City and other locations along the river, where cliff swallows often nest in the easily excavatable vertical faces.

There are maps denoting these various soils, and even in the areas described above, there are many varieties of soil with different characteristics. Soils are the major definer of what a roadbed or fill will be like, and they often define the ultimate performance of the structure built on them.

Soils are disturbed when moved, and once moved, they never regain their original state. By compaction methods and the addition of water or chemicals like lime, we attempt to pack and re-stabilize the soil in a denser form than is natural to form a permanent foundation. Water is the one common destroyer of such foundations. A dry soil is a stable one; water intrusion invariably causes problems. Anything you can do to proof or shed water from the soil will be beneficial.

Soil is poor man's rock for construction. There is only poor and worse soil for making foundations. But by virtue of economics and there being a lot of it in places, we often must use it as a building material. The larger the particles, the better—and don't forget to keep the water out.

AGGREGATES

You can call it rock; you can call it stone. You can call it sand or gravel. But to a highway professional, it is *aggregate*. Aggregate can be *fine* or *coarse*.

It is true that aggregate is the rock we were just discussing. But for the layman, when we turn that rock into a sized building material less than three inches in diameter by grinding, screening, or other manipulation, we call it aggregate. Coarse aggregate has particles ranging from three-eighth to three inches in diameter, and anything less than three-eighth an inch is considered fine (like sand).

Aggregates can come from several sources. It may come from solid bedrock formations (igneous or sedimentary), which are blasted, crushed, and screened into smaller sizes. It may also come from natural degradation sources, such as creek or river gravel, which consists of igneous or sedimentary rock that has been broken or worn off and carried hundreds of miles, maybe for hundreds of years, until it reaches its particle size. Such materials are dredged or scooped from their deposits and screened or crushed to size. Since aggregate comes from rock, and rock in Missouri has specific origins, we can discuss specific aggregates typically used in Missouri construction.

Easily accessible sedimentary rock comes from surface mines all over, commonly limestone. Dolomite is a similar material to the eye, but chemically different. Limestone is predominantly calcium carbonate. Dolomite is predominantly magnesium carbonate. Many sedimentary rocks are varying mixtures of either. The purist differentiates, but for the rest of this discussion, we will term it all limestone.

Crushed limestone is a soft aggregate, containing particles of whatever else in the ledges is being worked, such as shale or chert particles and soft stone. Certain formations have specific physical characteristics because of the chemical makeup and method of deposition. Tests can indicate which will perform better for highway work and withstand Missouri's moist, freezing, thawing environment.

Missouri and the central Midwest have one of the harshest pavement conditions in the US. The presence of moisture means that when water is frozen, it expands and destroys whatever rigid container it might be in, such as a rock void. Freezing once and staying that way isn't bad. But the Midwest has many freeze-thaw cycles, thus creating much damage due to the microscopic movement that occurs in the presence of moisture. Dry areas do not have this problem, nor do northern areas which are wet but remain frozen. It is the presence of moisture and the recurring freeze-thaw cycle that results in the problem.

Beyond igneous aggregate, the remaining sources are gravel or waterborne aggregate. There are northern Missouri glacial deposits consisting of igneous and other rock that have been transported great distances south. These deposits have been dredged and the gravel sized and sorted. They tend to be generally good, sound gravel because of their origin, and have been used for concrete pavements. However, they are no longer used, and the deposits are somewhat localized. Typical northern Missouri creek gravel is poor quality because of its origins in the local sedimentary rock. But southern Missouri gravels tend to be high in chert content; chert is very durable and outlasts the limestone as it tumbles downstream.

Missouri chert gravel does not typically perform well in asphalt or concrete, and is rarely used, with some exceptions. The remaining aggregate source is Missouri/Mississippi sand. This sand is siliceous sand (high in silica content, like chert). This is often used and is considered the staple for fine aggregate. It is also sourced from the north.

Southwest Missouri has problems getting Missouri River sand, and often uses Kansas or Arkansas River sand. Southwest Missouri also uses some limestone sands.

In short, we generally build Missouri highway structures out of limestone coarse aggregate and Missouri River sand because it's there, works best with what is available and is in the quantity needed.

Aggregates have several important, measurable characteristics. A desirable aggregate is dense, non-absorptive, hard and wears down in a way that leaves it just as angular as the original surface. It is also resistant to freeze-thaw damage when saturated with water. Limestone aggregates generally have none of these characteristics. So, we use the best of what we have.

Soundness is a measure of an aggregate's resistance to damage when it is frozen and thawed in moist conditions. When water freezes, it expands and can exert tremendous pressure. A good aggregate either will not absorb water at all (unlikely for most rock) or has pores and capillaries such that the water can easily move, like a sponge (again, not common for most sedimentary rock). Freeze-thaw cycle tests are run to see if the aggregate will meet a minimum standard of soundness.

The Los Angeles (LA) abrasion test is a measure of how hard an aggregate is and how it will wear. Aggregate is placed in a drum with steel balls and rotated to see how fast it will break down. Good aggregates resist breaking down.

Absorption is indicative of the soundness and LA abrasion test. Highly absorptive aggregates are not generally desirable. Not only do they tend to require too much cementitious material, but they hold water in an undesirable fashion. A possible exception to that rule is for specialized applications, which can require hard but absorptive aggregates. Those can form surfaces that don't wear smoothly, as the broken portion tends to be as rough or rougher than the original.

Hard and dense is best. Igneous materials tend to meet that property. Sedimentary ones do not.

Once the inherent characteristics of the aggregate are decided, we become concerned with quality—how well the aggregate group represents the inherent qualities, or whether it is contaminated. Is there soft, deleterious or foreign material present? All these characteristics are typically set out in specifications. The final aggregate should come from an approved source with approved characteristics and acceptable quality.

The final measure of an aggregate is *gradation*, a measure of the particle sizes present. For example, an aggregate with 100 percent (by weight) passes a two-inch sieve. But that could describe a lot of different materials. So, we can narrow it down as: 100 percent passing two inches, 50 percent passing a half-inch and two percent passing the #200 (200 openings per inch). There are an unlimited number of gradations we could specify, each with its own characteristics. An expert might look at that data and readily recognize that it is a clean rock, i.e., it does not have any clay fines in it. It may not pack very well but might drain water very well. If we had a similar gradation, with 35 percent passing the #200, we might have an aggregate that packs well and can hold traffic loads but would also pond water. So, gradation is crucial to specific engineering applications.

Perhaps gradations are best understood by the example of a 55-gallon drum filled with basketballs. This is an *open-graded* aggregate. It has a lot of voids. It would allow water flow easily, and typically be unstable if it weren't in the drum. We might take the same drum and basketballs, then start adding softballs into the voids between the basketballs. Then we would add golf balls to the voids between the softballs. Then marbles to the remaining voids. If we got point-to-point contact between each of the balls, we would have a *dense-graded* aggregate, which has many small voids, but would not allow water flow as easily. If it were more angular particles instead of balls, it would be interlocked and a stable mixture that could bear loads. If we went back to just the basketballs, and only added marbles, we would have a

gap-graded aggregate, with some sizes missing. Each gradation and the variations in between have some purpose and use. Typically, a gradation is designed by what is naturally available and what is needed for the job.
The largest volume of construction material used in highway construction is soil. Millions of cubic yards of soil are moved to prepare foundations for highway structures. The volume is so vast that it is virtually impossible to do anything other than use what is there. On occasion, engineers might add some soil modifier.

Soil or rock is not just necessary for a foundation; it is the foundation, because there is no choice. But once you get the foundation arranged in a stable manner, you start to have choices. Aggregates are the filler material to get a structure built and are a substitute for more expensive materials. Aggregate quantities used for many civil engineering structures are so large that they generally limit transportation over a long distance.

In general, for civil engineering applications, aggregates are in a range of quality applications: Base is a low type of application, kind of like a foundation. It doesn't have to be too good; it just has to hold up what's next. If it breaks up a little, no harm is done. For some uses, we may want something better than base material. At the high end are applications such as for asphalt or concrete. Here, we want a stable, clean aggregate with good characteristics.

Aggregates without any treatment may be used for bases, drainage, low-type roads and so on. Or they become an integral part of some treatment process, such as an asphalt mixture, concrete mixture, or other compound. But they generally function as a structural filler that is cheaper than the alternative.

One might think that because rocks are so plentiful, aggregates would be unlimited. But aggregate sources for engineering structures are becoming limited in the Midwest. The easiest surface exposures are always used first. Many are close to cities, where they become hard to access. And it is extremely time-consuming and expensive to open a new source, due to environmental concerns. The fact that Missouri has limited good-quality sources, limited exposures and a growing population makes the viability of a future cheap major highway expansion questionable.

CONCRETE

Let's get one thing straight before we begin: Concrete is <u>not</u> cement, and cement is <u>not</u> concrete, and the terms are <u>not</u> interchangeable. Now that we have that established, let's talk concrete and its components.

Basic concrete is a mixture of water, aggregate and cementitious material. It is mixed and left in a fluid state while it is transported to a final location, where it hardens to a solid and becomes a structural unit or a higher-quality filler. We can add various additives for specific purposes. The water is nothing different than what you might drink. If you wouldn't drink it, the impurities mean it is probably not good for making concrete, with some exceptions. We've already talked about aggregates. For concrete,

a clean, well graded, high-quality aggregate is needed as a filler for the expensive cementitious material. The aggregate does not generally react or otherwise contribute other than as a filler, with some exceptions related to gradation. And the gradation can affect some of the other concrete properties.
The cementitious material is the interesting aspect of concrete. It provides the properties we look for in concrete. There are various forms of cementitious materials available. Historically, the most familiar is Portland cement. It is a variation of the cement used by the Romans, who burned lime and mixed it with volcanic ash to form a hydraulic cement: one which reacts with water. Portland cement was developed in the late 1800s and is not much changed today. It is primarily limestone, some clay and shales, mixed with a few other minerals, ground into a slurry, dried and reground to ultimately form a dust compound that, when mixed with water, sets into a solid, with the aggregate providing a filler to expand the cement volume.

Typically, cement plants are located where raw materials are present (Missouri has several such locations), such as the right proportion of limestone and shales, and the rest of the material is imported. The final product is shipped in powder form by tankers, barges, or rail. There are several types of cement. Most common are Type 1, normal-use cement, and Type 3, fast-setting cement.

Today, there are several other forms of cementitious products on the market. Some are used by themselves or as a supplement to Portland cement. Many are blended with Portland cement and offered as other types such as Type IP ("one P") or IS ("one S") for general or specific purposes. Several of these products are worthy of discussion.

Fly ash is a power plant byproduct of coal burning. The particles collected are very small and round. Some fly ash from specific coals has their own cementing characteristics and may set when mixed with water. Others will form secondary reactions with Portland cement and water, adding to the cementing process. Fly ash can contribute to a concrete mixture when used properly. Unfortunately, out of ignorance and greed, some suppliers and users think fly ash can be directly substituted for Portland, and if a little is good, more is better. Since cement is $85 per ton and fly ash is $20 per ton, it's easy to see how one might make that assumption. Typically, in the Midwest fly ashes are, and can be, substituted for Portland in the 10 to 15 percent range, with no harm and sometimes to some benefit. There are reports of as much as 25 to 30 percent or more in urban areas, which is without exception a poor choice for Midwest fly ash. Some Canadian fly ashes are reportedly used at up to 100 percent replacement. Fly ash is also sold intergrown with Portland cement as a Type IP cement and some other variations.

Silica fume (SF) is another waste product, from the silicon industry. It is like fly ash in that it is a precipitate from manufacturing something else, in this case silicon products. It is composed of extremely small, round particles, and in its dry state, it may flow where water will not. It also is good at forming secondary reactions and adding to the cementing process, densifying the concrete by filling microscopic voids. It is somewhat expensive and used in smaller quantities. Typically, 58 percent Portland replacement is used.

A more common product of the last decade is *ground granulated blast furnace slag* (GGBFS), a byproduct of the steel industry. Thousands, perhaps millions, of tons of waste slag from steel making has been dumped over the years. It is now being re-processed and ground into a powder that is both a hydraulic cement and compatible with Portland cement. It is also sold intergrown with Portland cement as a Type IS cement.

GGBFS is typically substituted at the rate of 25 percent by weight of the Portland cement. Proponents argue for higher quantities. Its strength seems to be as an additive, not as the primary cementing agent. And it can have some undesirable properties when used in high percentages. Again, the lower unit cost seems to be the driving force to substitute higher quantities, not improved concrete.

Probably one of the more significant effects of concrete additives is air entrainment. Years ago, it was noted that when concrete was mixed with some animal fats, it was more durable under freeze-thaw conditions. It was discovered that microscopic bubbles were created, the form of which remained when the concrete hardened. When concrete was water-saturated and frozen, these bubbles provided relief for the expanding, freezing water inside the concrete, vastly improving performance under freeze-thaw conditions. The standard today calls for roughly five to seven percent air (by volume) to be “entrained” in concrete to be exposed to freezing conditions. Entrapped air is visible to the naked eye and is not useful. Entrained air is microscopic, and what is desired.

There are numerous other additives to slow down the setting time (normally 30 to 60 minutes) indefinitely, reduce the water demand, make it set faster, make it more fluid and many other specific applications. In fact, today’s concretes have become chemically complex. Most of it ultimately gets hard. But sometimes long-term performance is another story.

The manufacture of concrete is relatively simple. The single, most significant aspect of concrete is the water/cement ratio, or w/c. While it can be expressed in different manners, the most common is simply the weight of water divided by the weight of cement in a unit of concrete. If in a cubic yard (27 cubic feet) of concrete, we use 240 pounds of water and 600 pounds of cement, we have a 0.40 water/cement ratio (240/600).

This ratio is what provides concrete with most of its properties. High amounts of water relative to the amount of cement (high w/c) is usually not good. It results in weak, porous, non-durable concrete. Low w/c is considered good and can result in high strength, dense, durable concrete. A w/c of more than 0.45 or so is beginning to be less desirable. However, concretes with less than 0.25 to 0.30 w/c do not have enough water to activate the cement. With no additive use, normal concretes will run 0.40 or more. With additives, one can easily attain sub-0.30 values.

There is also some value in the quantity of cement used. It typically adds improved qualities, within reason. It is of little value, for instance, to use a seven-bag mix, and add a lot of water. One could probably use a five-bag mix with much less water (low w/c) and obtain better properties. There is some balance that should be obtained. But given an identical w/c, higher cement contents provide enhanced concretes.

Concrete mix design first determines how much cement is needed, and then a w/c ratio is chosen. That determines how much of each cubic yard is filled with the grout (water-cement mixture). If we want air, we take out a specified volume for it. We then proceed to fill the remaining volume with coarse and fine aggregate, typically more coarse than fine. Those weights then make up the “batch weights” for a concrete supplier.

Concrete in its initial form is liquid. That liquid flowability is typically measured by *slump*. Slump is how much the concrete slumps from a 12-inch height, when stacked up in a standardized test. One-inch slump is very stiff and has a low water or paste content. Eight-inch slump concrete will hardly stand up and readily flows when released. Low slump concrete produces a more durable finished product than high-slump concrete because it contains less water.

The conversion of concrete from liquid to solid is the *set time*. Set time is a function of the cementitious products and additives used. Typical unaltered set times are in the range of 90 minutes at 70 degrees Fahrenheit. Hotter temperatures accelerate setting and cooler ones slow it down. Below approximately 40 degrees there is little setting and somewhere below freezing, the water in the mixture will freeze. While frozen, wet concrete may ultimately get hard, it may never recover from the expansion damage.

The set process is somewhat complex chemically, but it involves use of water to form hardened, crystallized products (hydration). If water is not present, all hydration ceases. For this reason, the *curing* process is very significant to concrete. Curing concrete means retaining all the water you put in it. While it may be true that at 0.45 w/c you have excess water, you can easily dry out the outside. And once water leaves, it is extremely difficult to regain it, even in saturated conditions. Typical curing is by plastic covering or sprayed cure compounds that reduce moisture loss.

Curing may continue indefinitely. Concretes 50 years and older have been recorded as still increasing in strength. But the practical period is much shorter. Because strength is a good measure of concrete cure, we can use it as a reference. A common concrete may have an ultimate strength of 5,000 pounds per square inch (psi); that is the force it can withstand. When cast, its strength is zero psi; at 12 hours it might be 500 psi. By day three, we may reach 2,000 psi, and 3,500 psi by day seven. By day seven it is starting to slow, until we perhaps reach 4,700 psi at 28 days. 28 days is a standard measure, and unless otherwise specified, is the point at which we measure strength. But with moisture and unhydrated cement products still available, the concrete may continue hydration, picking up another 200 psi the first year and another 100 psi over the next 10 years. It is important to keep the hydration process going for as long as there is anything to hydrate.

Common commercial building strengths may be 3,000, 4,000 or 5,000 psi, or any variation between. Those strengths are generally attainable using common aggregates, four to six sacks of cementitious material and a lower w/c. Strengths above that are easily attainable and used in more exotic construction. The higher the strength, the more critical materials, handling, and curing become. At about 10,000 psi, the cement paste is becoming stronger than the aggregates used to make it. And there are even concretes that go up to 20,000 psi.

It is easy to see how concrete has become a favorite tool for building. It handles easily, is strong and resists many elements. In the hardened state and formulated properly, concrete is water-resistant, resistant to many chemicals and weather and can form a structure that lasts for centuries. But it can also suffer from internal chemical reactions, abrasion, erosion, chemical damage and so on. It is probably one of the most abused mass building materials, yet it continues to perform.

ASPHALT

Just as concrete is the unmatched king of civil engineering structure building, asphalt fills a niche in the arsenal of the highway engineer. There is considerable confusion in the industry about terms. Raw asphalt—the black sticky, liquid stuff—is called asphalt, bitumen, binder, tar, and other terms. Most are applicable, except for tar. Tar is a pine resin product derived from coal. Mixtures containing asphalt and aggregate are also termed asphalt. For the purposes of this discussion, we will speak of asphalt as being the black sticky stuff. "Asphalt mixtures" will be used for those mixtures of aggregate and asphalt commonly used in pavements.

One of the earlier versions of Moses in the bulrushes has the basket coated with a bituminous material to keep it waterproof. Asphalt has been used for thousands of years. It's a natural secretion from shallow crude oil deposits, where the volatiles evaporate, leaving a thick, gooey, moisture-resistant black material. There are still tar pits in parts of the world, where dinosaurs got stuck and birds still are. It also occurs less naturally in the crude oil refining process, where the desirable lighter forms are removed as white gas, car gas, diesel, oils, and waxes. What is left is asphalt.

Early refiners in the eastern US had the original problem of figuring out what to do with this junk. It was commonly disposed of in pits and other means because it was too thick to do anything useful with. Around the same time, the automobile became popular. It used the lighter form of crude (gasoline) and needed a smooth surface to drive on. Automobile development is probably the major reason for the development of the "bottom of the barrel" asphalt product.

The original asphalt was a matrix of asphaltenes, oils, waxes and everything that could not be taken out by evaporative refining. As refining became more efficient, the remaining asphalt became more and more of a junk pile. And in recent years, development of coking processes that could even make use of that made asphalt a more valuable product instead of an end-result waste product.

Road asphalt is typically categorized in terms of fluidity. When you take most of the volatiles, waxes, and oils out of crude, you are left with a mostly hard, black cake of stuff. Warm it up enough and it will become sticky. Cool it off and drop it on the floor, and it will shatter. Although there have been various ways of describing asphalt, an earlier common method was by penetration: how far a needle would drop into a sample at a specified temperature with a specified weight. It had little to do with engineering properties, and measured only how hard it was at ambient temperatures. A typical asphalt grade was 60-70, indicating the penetration range of that grade. A softer grade was therefore 85-100, indicating a higher penetration. But that was about all that was measured, and you can hide a lot of junk in those categories. In the 1970s, another measure was developed based on engineering viscosities. Other properties were added, and now the old 60-70 became AC 20. The new standard had more engineering property requirements. AC 10 was comparable to the old 85-100. Then in the early 1990s, under the auspices of the Strategic Highway Research Program (SHRP), a series of specific engineering requirements for asphalt deemed necessary for highway work were developed. With this change, asphalt was no longer the bottom of the barrel material. It was now an engineered material with specific properties. The new grades were performance grades, or PG, asphalt. With the right properties, the old AC 20 might be a PG 64-22.

PG asphalt is described by a high and low temperature attribute. For example, PG 64-22 is an asphalt resistant to certain loads in the 64-degree Celsius range and resistant to cracking at the -22 degree C range. The high and low values move in six-degree increments. Depending on the environment, some states may specify a 58-28 or a 70-22, for example. It turns out that there is a maximum practical limit to the temperature spread (high minus low) for petroleum asphalt cement. At first, the refiners claimed they could only cover a spread of 86 degrees C. That is, you could have a 58-28 or a 70-16, but nothing wider. But it turned out that by doing some crude oil selection and watching the refining process, refiners could hit a 92 degree C spread.

In the meanwhile, other suppliers are creating additional spread by adding polymers, which will resist cold cracking, yet be flexible and resist movement at high temperatures. Refiners have an inherent problem in that crude oil is not refined for the asphalt. Those who use an additive to get it face higher costs.

MoDOT uses a 64-22 (a carefully refined asphalt) as standard due to cost only. Some 70-22 (very carefully refined) are specified, with occasional 76-22 (polymer enhanced asphalt) specified. Ideally, in the Midwest, a minimum of 70-22 is needed, and preferably 76 or higher. There is no real limit as to how high or how low could be used. Again, the issue is, can it resist cold weather cracking, yet resist movement under loading when hot?

Use of a naturally hard material is difficult. The early method was to heat it up and get it in place before it cooled off. Early in the 1900s, they figured out that one could take the final asphalt, then remix it with a petroleum product that would evaporate, leaving the hardened asphalt. Hence, there were forms of slow cure, or SC, liquid asphalts that contained the equivalent of diesel. These were slow to cure, remaining tacky for long periods of time. Medium cures (MC) used something like kerosene as an evaporator, while rapid cures (RC) used the equivalent of gasoline. One can easily imagine the potency of such vapors from these materials, particularly when heated, as was common. And indeed, there are many stories of explosions and burning roads.

It was not so much the dangers, but environmental concerns that brought a halt to the liquid asphalt. They worked well but put volatile chemicals in the air. That led to the development of emulsions. By shearing asphalt into tiny pieces with a colloid mill and adding a little soap and chemistry, one can suspend those asphalt particles in water, a process called emulsion. The emulsion is sprayed and then “breaks,” allowing the asphalt particles to coalesce into hard asphalt as the water evaporates. Emulsion is somewhat hard to use and generally not as effective engineering-wise, but there is no question that it is environmentally better and safer.

Liquid asphalt is used for tacking, priming and maintenance applications with little or no heat. PG asphalt is used in hot mix applications, where the asphalt is liquefied by heat. This takes us to the subject of asphalt mixtures.

Asphalt mixtures are somewhat analogous to concrete in that they are cement (asphalt) plus a graded aggregate, with a void content and specific proportions of each ingredient. However, for asphalt mixtures, aggregate gradations are critical. Not only do they form the matrix that makes room for other components, but they form the weight-bearing structure. Aggregates are the load bearing skeleton of the asphalt mixture.

A hot mix asphalt mixture typically consists of asphalt (in the range of four to six percent), several separate aggregate fractions (sizes), each providing certain gradations and other characteristics, a space between the aggregates termed Voids in Mineral Aggregates (VMA), and an air void content in the four to five percent range. For mix design, mixtures with varying proportions are heated and compacted in the laboratory to replicate compaction on the roadway. Measurement of resultant air voids and other characteristics determine the final mix design. Again, coarse aggregates are the workhorse of the structure, with the fine aggregates acting as filler and stabilizers.

There are several methods of mix design. Most are empirically derived. Hveem method, Marshall mix design, direct compression and others have been used. The SHRP research also resulted in a new asphalt mix design method that many states now use called Superpave.

Understanding the terminology is key—PG asphalts are a descriptive measure of the asphalt properties. Superpave is an asphalt mix design process with specified engineering properties. They are not the same materials or properties, nor even related, other than they were developed in the same period. You can make Superpave asphalt mixtures out of aggregates and any form of asphalt—penetration graded, viscosity graded, or performance graded. So, Superpave does not describe asphalt. Since PG asphalt is commonly the product sold, and Superpave is the new design process now used, they happen to have connections.

When we start discussing material properties using engineering terms that have value, rather than relying on empirically derived values, we become smarter about designing our products. This was one of the main arguments for the development of Superpave and PG asphalt. Both products attempt to describe a process that can be engineered with reason, rather than guesswork and empirical evidence.

Superpave mix design is an effort to compact and measure mixes in the laboratory, as well as to measure the engineering properties of those mixtures. Materials are heated, mixed and compressed in a gyratory, kneading compactor under load. A mix which compacts to zero voids may be flexible, but it will likely rut under load. On the other hand, one which cannot be compacted and contains a high void content, say 10 percent, will be hard to field compact and will also allow water penetration and oxidation, which will shorten its lifespan. Ideally, there should be about five percent voids after all compaction is finished. Much more, and the mix becomes permeable. Less, and there is no room for asphalt movement as it shrinks and swells. At under two percent, the mixture tends to become plastic under load, acting much as a fluid.

The goal of mix design is to a) estimate the load to be applied on the roadway (often estimated by traffic), b) determine how much load to apply in the laboratory, and c) replicate the field conditions. Ultimately, mix design and field use go hand in hand.

But at some point, the value of asphalt mixtures for some high type pavements becomes questionable. At one time, their value was the ease of placement and flexibility under load over poor bases. Asphalt served as a poor man's road covering. Many current asphalt mixtures, under today's traffic, are required to be of a rigidity like concrete, requiring the same or an even better base. The lifespan of existing exposed asphalt is inherently less than Portland cement concrete, given a good design and materials for both. So, there is a balance that is often struck between the mixture's expectant life and ease and cost of placement.

STEEL

Steel is a critical highway structural component. Of all the materials discussed so far, none have enough tensile strength to amount to anything. That is, if you attempted to pull them apart, you could, with relative ease. For example, although concrete is very strong when compressed and may support loads in the range of 5,000 to 10,000 psi, it will only resist a load of 700 to 1,000 psi at most when placed in tension.

When we put concrete under load, it is likely that all the strain is not compression; somewhere the unit is in tension. And when we can add something to improve this quality, we can drastically improve structural designs. It turns out that steel has anywhere from 40,000 to 270,000 psi or more when placed in tension, depending on its grade. Hence, we can add small amounts of steel strands (reinforcing bars) at strategic places where the concrete might be in tension and significantly reduce the amount of concrete we would otherwise need.

Steel is also used for crack control. In this case, the steel is not providing any considerable strength, but instead keeps the concrete together so it continues to act as a unit. For example, wire mesh is commonly placed in pavements or sidewalks.

Under normal conditions, steel surrounded by alkaline concrete is completely protected from rusting. But that is seldom the case. Either the concrete cracks for some reason, which in fact it must do to take the full tensile effect of the steel, or the steel is exposed at some location. Therein lies the problem.

Once steel can be touched by water via cracks or exposure, it can also be touched by chlorides that are naturally present, especially in winter salt treatments on highways. Chlorides and water create “batteries” in steel, much like a car battery. A current is created as electrons circulate while attempting to equalize as the steel oxidizes (rusts). Rust takes up much more volume than the original steel, so the area pushes against the surrounding concrete. But remember, the concrete is weak in tension, so it will not take much pushing, readily giving way to cracks, potholes and edge breakage and introducing more water and chlorides—an ongoing, vicious cycle of disintegration.

Thus, one of the major deterioration processes of our highway system is the rusting of steel. Not only does rusting destroy the surrounding concrete, it also reduces the amount of good steel taking the tensile load, until eventually the steel fails, thus failing the structure. Remember, the steel is taking the tensile load by itself. Maintenance then becomes a race to attempt to prevent this rusting process.

There are several approaches to rust prevention. The first is to use a non-rusting product. In recent years, stainless steel has been tested for effectiveness in structures. While significantly more expensive than black steel, the fact that the steel is typically a lower fraction of the total structure cost when compared to the concrete mass, labor and mobilization, plus the extended life, can make stainless the cheapest product for the life cycle. Others are experimenting with polymers and fibers. Plastic, fiberglass, carbon fibers and others are possible solutions; however, they have their own problems. Plastic seems ideal, until one understands its relaxation under load. Stainless or other non-rusting steel seems to be the most effective, as it is a familiar product and does not involve new engineering. But in the future, fibers will undoubtedly play a major role.

A second approach is a hybrid one. You take the rusting steel and coat it with a non-rusting product. The most common use in the past 20 years has been epoxy coated steel, which is used in most structures today and is known as the common “green” steel. The concept is that all the steel is protected from chloride contact. While valid in theory, in practical use, the coating is easily damaged, which in turn leads to concentrated batteries that can be worse than no coating. There are also some questions about the effect of the coating on the adhesion needed between the concrete matrix and steel. All in all, the use of epoxy steel seems to be effective in many applications to date, but it does not fix the problem.

There are other coatings for the hybrid approach. A more recent one is stainless clad bar, where the black bar is manufactured with a thin stainless coating. While effective, it still has the problem of exposed steel when the coating is penetrated.

The third approach is chemical. There are products that can prevent the steel from reacting with chlorides by altering the electron flow or stabilizing the surface. Some of these materials can reportedly be applied even after rusting starts.

Another interesting approach is electrical, termed cathodic protection. The batteries set up by corrosion are nearly one volt. If one applies 1.1 volt of direct current but in the reverse direction, the corrosion process is halted. This approach is done today on many older bridges. The effectiveness is questionable, due to the problem of getting the right current on the right battery. If applied in the wrong location, the electric current may aid corrosion, and it is virtually impossible to control all locations this way.

The latest approach is to saturate the structure and “suck out” the chlorides, then seal them from re-entry. This approach has similar problems to cathodic protection: deteriorating structures are creatures of many variations and difficult to cure in reverse.

The answer to steel corrosion is to keep it from happening. The question is how to do that effectively. Ultimately, the use of non-corroding products will probably be the primary solution, provided they do not introduce other problems.

PAVEMENTS AND STRUCTURES

It makes sense to conclude with pavements and structures, as they are the compilation of the materials discussed in the previous sections: soils, rocks, aggregates, concrete and asphalt mixtures. The complexity lies in putting these elements together in a usable transportation matrix to carry today’s loads.

Early civilization roads were made of many things. We already discussed the Roman stone roads, parts of which still exist today. Even earlier, the Great Wall of China and many other civil engineering structures formed smooth, load bearing transportation units. In the early formation of the US transportation, logs were split or cut and laid crossways to form a way to get out of the mud. Since then, we’ve graduated a little, but the questions are the same: Will it support the load? Is it smooth? Will it last?

How do you meet the above requirements with soil or rock? We already know the worst-case material is soil. With no alterations, it takes on water and supports very little weight. However, by using select soils and compacting them, we can seal out some water, stabilize them and increase the load bearing capacity. Often, water itself is used as the agent to manipulate the soil. Other agents, such as lime or fly ash, are used to chemically modify certain soils. Some agents dry up the soils or add cementing action (as with cement or fly ash), some flocculate them by causing the fine particles to cling together (lime in clay) and some draw moisture (calcium chloride), thus keeping the soil in a damp condition. Still others may add a polymer type structure to the soil to give it to somebody. In most cases, while the resulting structure may be strong, it typically has some dust and is not very permanent. Low type uses, such as local municipalities and counties, may often have such roads. Such treatments also may be used to stabilize a roadbed prior to adding a higher type of structure.

Rock is often added to bind the soil— “graveling the road” is the rural term. When mixed with aggregate, soil becomes the binder to hold a stronger matrix in place, much like an asphalt mixture. Sometimes graded aggregate is necessary, while other times a stable product containing fines is necessary. While the resulting roadway becomes more stable, the surface is still dusty. If one of the additives above does not solve the issue, the correction may call for additional action. Here is where we get into our real pavements.
Following are several pavement treatments, along with their materials and common uses, listed from low to high type:

Base Stabilization: Mixing existing or imported base materials with various admixtures to improve engineering qualities, particularly strength. Additives may include polymers, asphalt, cementitious products, lime or other drying, chemically active, or binding materials. Typically applied in thick layers (four inches) and has a wearing surface applied afterward.

Prime Coat: Liquid asphalt applied to a puddling condition, intended to soak in the surface and bind the top materials. Not wear resistant and often used as the first application for subsequent layers.

Tack Coat: Like a prime coat, but non-penetrating and applied to nonabsorbent surfaces. Used to bind one surface to a subsequent one.

Chip and Seal: Often the first choice for upgrading a dirt or gravel roadway. Heated or liquid asphalt is applied in a thick layer. A layer of one-sized aggregate is spread over the top to blot the asphalt and provide a riding surface. The resulting layer is thin and flexible.

Macadam: An older application, rarely used anymore, but worthy of mention. A layer of larger, one-sized aggregate is primed with asphalt, or water is used for improved stabilization. Subsequent layers of smaller stone that fit into the voids of the larger aggregate underneath are applied, rolling as the surface is built up. A very stable surface, but labor intensive.

Blade Mix: A mixture of select aggregate gradation mixed with liquid asphalt at ambient temperatures to form an asphalt mixture. This was the standard of many older maintenance sheds. When the material is spread on the roadway, the evaporates leave and the mixture sets. With the advent of emulsion, the same thing can be done, but storage becomes a problem. Recall that it used water as the liquefier. But by adding some softer ingredients, it can be made to work.

Slurry Seals, Micro surfacing and Sand Seals: Mixtures of an aggregate and usually a specialized emulsion product, often mixed and spread on in a thin lift (less than a half-inch) with the intent to modify or seal the wearing surface.

Note that most low type applications have a form of asphalt as an ingredient. That is because it can be used to make thin, but flexible, dustless layers.

Recycled Asphalt: Use of asphalt pavement, typically reduced to small particles, with rejuvenators or new cementitious material added, and reapplied in a lift of one to six inches. May be mixed in place or off-site. The smaller the reduction, the better the rejuvenation and ultimate performance. The problem is in getting uniform rejuvenation.

Recycled Concrete: Use of concrete, typically reduced to small particles and used as an aggregate in base, concrete or asphalt. The problem is that this form is usually a lower quality aggregate than that available locally, and harder to use. It is typically more porous, softer and more angular.

Hot Asphalt Mixtures: Mixtures of aggregate and asphalt, mixed, applied and compacted in one- to six-inch lifts to form structural pavements. Additional lifts may be applied for increased structural thickness. There are various forms of mix design and materials, but the use of them is critical.

White topping: Thin lift of three to five inches of concrete typically bonded over the top of older asphalt structure. Can be on top of old concrete, where it is called concrete overlay.

Concrete: Concrete mixtures applied in a single lift of varying thickness (6 to 20 inches) to form structural pavement. Also used in building applications for most structures.

The ultimate problem of transportation structures is to balance economics (total cost and funding available) with quality (ultimate performance). The Romans built roads of compacted and hand-placed stones so thick, they are still carrying traffic 2,000 years later, albeit somewhat roughly. These roads wore from the top down.

Engineering has become the process of attempting to build what you can afford, to get the most value for your money with what you have available to spend. The need for public facilities like roads, central buildings, and utilities often last forever, or close to it. We can generate the interest to build them once, but seldom again—and we will attempt to use them forever. It is interesting that in today's world we have decided that they must have a lifespan.

Pavement structure failures in Missouri are usually due to a failure of the base or material. Base failure is when whatever is supporting the structure relaxes or shifts and overstresses the structural unit. Pavements crack when the base is not what it was designed to be, or it is loaded with more than what it was designed to carry. Want to eliminate base failure? Put it on bedrock, or some similar form of structure. The Romans built their roads so thick; it was immaterial as to what they were laid on. Water often intrudes and softens, swells, or otherwise modifies (never for the better) base characteristics.

Material failure occurs as either the weathering process (in the form of the freeze-thaw cycle, ultraviolet and so on) or chemical interactions alter the materials to a different state where they are no longer effective. It is possible to create manmade materials, such as ceramics, that are extremely uniform and stable.

Anytime we use Mother Nature's aggregates, we are subject to variations. Many states have better aggregates. In Missouri, we have a few good ones. But it is usually deemed unnecessary to haul them very far, due to transportation costs. Hence, we live with something less than the best.

Somehow, we must attempt to put all this together into a transportation system.

WHAT WENT WRONG

The following solutions presented by BioSpan are essentially the same solution—**DON'T** let it break in the **FIRST** place! BioSpan's focus is pavement preservation.

Once the pavement is distressed, it is ***broken***. We should **NOT** have let it get that far, but we cannot avoid driving on the roads and the roads cannot escape the weather.

This manual lists a variety of ways the roads will break. There are two sections—Asphalt and Concrete—two material types with separate components and mix designs.

Once the surface is broken, the best we can hope for is a band-aid fix and a little more time to shuffle budget dollars around to other projects. In the past, traditional fixes have included spotty patching or thin seals over the top of the problem using petroleum-based toxic products. These 'fixes' are temporary patches.

BioSpan products are meant to meet or exceed the maintenance goals while at the same time applying an environmental consciousness. Prevention is key! The environment is important! Saving dollars is ideal! We need to train our brains to think proactively and catch problems before they start.

Types Of Distress

There are two basic categories that define distress on paved surfaces: *load-associated* and *non-load-associated distress*.

Load-associated distresses are the result of forces delivered from traffic. Non-load-associated distresses relate to temperature, moisture, materials, and construction methods.

In this manual, some common pavement distresses work in concert with one another. One distress type or cause may lead to multiple other distress types. And almost every distress mentioned will deteriorate faster with traffic.

Distresses are there from day one. BioSpan has designed products to prevent distress from spreading. Some of these products may be used as temporary fixes.

ASPHALT DISTRESS

The following section outlines common asphalt distresses and the solutions from BioSpan, including the following products:

Activate
Reclaimed Asphalt Pavement Millings Restoration Agent
Activate is a 68% biobased liquid solution that restores 100 percent reclaimed asphalt pavement (RAP) millings to like-new asphalt. Activate mixes are good for filling potholes, edge ruts, shoulders, base layers, and even full driving surfaces.

RePlay
Agricultural Oil and Preservation Agent
RePlay is an 88% biobased, penetrating agent that preserves asphalt longer by improving resistance to the expected stresses. RePlay is spray-applied once every 3 to 5 years, with considerably less maintenance during that period.

BioTak-4600
Biobased Tack Coat
BioTak is a 71% biobased tack coat, spray applied BEFORE placing new asphalt overlays or patching. BioTak creates a polymer-modified bonding surface to connect new and old asphalt.

Activate, RePlay, and BioTak are built from synergistic biobased polymer technology and work in tandem to form a more secure bond. These unique polymers improve resistance to temperature cycles, tensile stresses, and brittleness.

Remember: Every BioSpan product must be applied on a CLEAN surface. The affected area must be clear of moisture and loose debris before treatment.

Alligator Cracking

The Problem

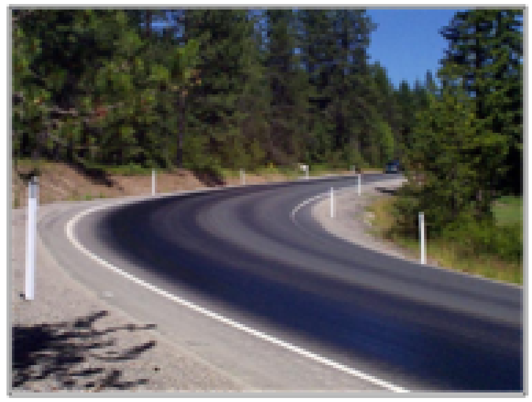
A multitude of interconnected cracks caused by fatigue failure of the surface under repeated traffic loads.

Cracking begins at the bottom of the asphalt layer, with high tensile stress, and reflects to the surface. Cracks eventually connect into many-sided, sharp-angled pieces that resemble an alligator's back. Thin pavements are more susceptible to earlier alligator cracking. Hairline cracks in this pattern are considered Spider cracking.

The Solution

1. Hairline Cracks: Apply RePlay to seal and prevent moisture penetration.
2. Small Areas: Remove the damaged surface by milling that layer. Then mix Activate with screened RAP millings to create a new patch for that section. Apply RePlay to both patch and adjacent asphalt surface for bonding.
3. Large Areas: Remove the damaged surface by milling that layer. Mix Activate with RAP to create a full overlay. Coat the new overlay with a RePlay application for added bonding strength.
4. Infra-Red treatment can soften a damaged surface and promote low-level crack sealing. Apply RePlay or Activate on top of this to bond for a longer period.

Bleeding



The Problem

Discoloration is commonly caused by excess asphaltic cement in the mix, low air void content or the overall quality of the asphalt pavement material itself.

There is too much liquid asphalt binder that softens in the sun and bleeds above the surface. It can be a shiny, glass-like, reflective surface. Bleeding may create an uneven, dangerous surface, especially when wet with oil and water.

The Solution

1. Minor bleeding: Apply RePlay to fill some of the larger pores in the matrix, restricting the amount of asphalt binder that can push through. RePlay polymers will also help stabilize the binder.
2. Heavier bleeding: Use Activate mixed with RAP for a new overlay. Apply RePlay to the new overlay for additional polymer bonding with Activate.

Block Cracking


The Problem

Interconnected stress cracks that divide the pavement into rectangular pieces.

Block Cracking creates large sections of asphalt separated by cracks. Block sections are primarily caused by shrinkage stress from daily temperature cycles. Blocks can range in size from approximately 1 to 100 square feet. Larger block sections are generally classified as longitudinal and transverse cracking. Block sections may crack into smaller sections and become alligator cracking.

The Solution

1. Low-Severity Cracks (1/4 inch and smaller): Apply RePlay to seal up hairline cracks and keep water out. Water increases damage from temperature cycling.
2. High-severity cracks (1/4 inch and larger): Remove and replace the cracked pavement layer with Activate and RAP millings. Coat with RePlay afterwards for additional bonding.
3. Crack Seal wider cracks when necessary. RePlay on top of the crack seal can improve the bond strength with the old asphalt.

Infra-Red treatment is impractical and costly because block sections are large in size and cracks cover more surface area.

Polymers in RePlay and Activate will improve resistance to thermal stress as well as bond strength.

Corrugation and Shoving

The Problem

A form of plastic movement typified by ripples (corrugation) or an abrupt wave (shoving) across the pavement surface. The distortion is perpendicular to the traffic direction.

The weather is warm, the asphalt is softened, and traffic starts and stops on the same point frequently. This is a common stress at stop light intersections or parking lot stalls. Sometimes it happens where hot mix asphalt (HMA) abuts a rigid object like curbs or roundabouts.

The Solution

1. Small Areas: Infra-Red treatment may re-soften and reform a section. Small areas may also be milled up and replaced using Activate and RAP, especially areas that but up against other rigid objects.
2. Large Areas: Create a new surface using Activate mixed with RAP, then coat the new overlay with a RePlay application for added bonding strength.

Depression / Settlement

The Problem

Localized pavement surface areas with slightly lower elevations than surrounding pavement. Depressions are very noticeable after rainfall, when they fill with water.

There is no easy fix here. The root cause of the stress is in the roots of the road. The foundation soil has settled or shifted. Sometimes the cause is improper compaction and construction. Other times it is from soil swelling from excessive moisture, usually clay. The worst-case scenario is a “wash out “of the road due to the elasticity of the subsurface.

The Solution

1. Remove the damaged surface to proper depth. Examine the subsurface and correct the deficiencies. “Elastic” sub- surface soils (clay, sand) should be stabilized with a solid rock base.
2. Activate and RAP may provide a strong base coarse replacement and/or driving surface. Remove affected pavement, dig out and replace the poor subgrade, then apply Activate matrix. Coat with RePlay for increased strength.

Joint Reflection Cracking

The Problem

Cracks that appear in a flexible asphalt overlay of rigid concrete pavement.

Asphalt surfaces are flexible and concrete surfaces are not. Asphalt surfaces are usually paved in large continuous layers, whereas Concrete is placed in separated slabs and measured joints. When a flexible (asphalt) surface is paved on top of a rigid (concrete) surface, the asphalt cannot flex properly. Thus, we get cracks in the asphalt that have reflected upwards from the joints between underlying concrete slabs.

Cracking is caused by movement in the rigid concrete slabs underneath, usually occurring in thermal or moisture expansion. Oftentimes, the concrete has not made use of dowels to offset the expanding and shifting stresses. Then traffic comes along to intensify the stress.

The Solution

1. Low-Severity Cracks (1/4 inch and less): RePlay may seal low-severity cracks and reduce water penetration into other surfaces. RePlay can improve flexibility and resistance to tensile stress.
2. High-severity cracks: Replace the distressed pavement using Activate and RAP. Crack Sealers may be used to fill wide cracks to avoid removing sections of pavement. Apply RePlay on top of either Activate surfaces or Crack Sealers to improve bonding.

Lane / Shoulder Drop-Off or Heave

The Problem

A difference in elevation between traffic lanes and shoulders.

Both Concrete and Asphalt pavements can have this separation of traffic lanes and shoulders. Outside edges can drop with settlement or pumping of subgrade. Sections can also rise from frost expansion or swelling. The goal is to level sections, so they are flush with each other. This can usually be done with full or partial new overlays.

Uneven asphalt surfaces can ravel at the exposed edges and lose material. This could also create edge cracks that spread. Proper subgrade construction and compaction may avoid such distress.

The Solution

1. RePlay may save the exposed edges from raveling and losing material.
2. Shoulder patches using Activate and RAP can create an even, flush surface. RePlay on top will add bond strength between old and new surfaces.

Longitudinal Cracking

The Problem

Cracks parallel to the pavement's centerline or lay-down direction.

The centerline joint between lanes is not perfect. Longitudinal cracks form on this joint because of fatigue. Thermal Shrinkage and Expansion, age hardening, or just plain traffic loads cause fatigue. If the distress is too prominent, it might be time to reconstruct the joint.

The Solution

1. Low-Severity Cracks: RePlay may seal up hairline joints to shield from water damage.
2. High-Severity Cracks: Crack Sealers may help bond the two surface lanes. RePlay on top will improve that bond between Crack Seal and old asphalt.

Patching

The Problem

An area of pavement that has been replaced with new material to repair existing pavement.

Patches are defects. Patches are temporary fixes to OTHER problems. Patches sometimes don’t stick if done improperly. Patches are usually asphalt. Even concrete surfaces are often patched using asphalt, which does not bond in the same manner.

The Solution

1. Asphalt Patch on Asphalt Road: BioTak will help bond the foreign patch with the original pavement.
2. Patch Cracks: Remove cracked areas AND old patches. Replace using Activate and RAP. Apply RePlay on the WHOLE area to improve bonding.
3. Infra-Red may soften patch AND surrounding asphalt. The affected area may be pre-treated using Activate. RePlay on the affected area afterwards will improve bonding.

RePlay on asphalt patches will help lessen water penetration, thus lessening thermal effects. New Activate patches in concert with RePlay increase bond and resistance.

Polished Aggregate

The Problem

Areas of asphalt pavement where the portion of aggregate extending above the asphalt binder is either very small or there are no rough or angular aggregate particles on the surface.

The aggregate rocks are exposed on the surface when the asphalt binder in between has worn away. These rocks grow smooth with repeated traffic or weather. They decrease skid resistance for traffic. The exposed aggregate will loosen and ravel away. This process repeats as binder wears away, aggregate loosens, and the next layer is affected.

The Solution

1. Apply RePlay for low-level severity exposed aggregate. RePlay will improve the bond between barely coated aggregate and remaining asphalt binder.
2. Remove the affected surface by milling. Replace with an overlay using Activate mixed with RAP millings. Apply RePlay afterwards for improved bonding.

Potholes


The Problem

Bowl-shaped depressions in the pavement surface that penetrate all the way through the asphalt layer to the base course.

Potholes are deep, with sharp edges and near-vertical sides. The loose asphalt material continues to ravel and grind off as the hole grows. Potholes form from other distresses such as pumping, settling, shrinkage, and cracking.

The Solution

1. Clear the hole of moisture and loose material. Sometimes smooth or square off pothole edges. Fill the space with a uniform bonding surface of BioTak-4600. Then insert a mix of Activate and RAP. Apply RePlay on top to improve bonding.

Raveling

The Problem

The progressive disintegration of an asphalt pavement layer from the surface downward as aggregate particles are dislodged.

The asphalt binder (glue) is brittle, oxidized, or worn off. This is typical of aging, weather, traffic, or poor mix design. The aggregate loosens and can be washed or blown away, causing the pavement to lose its structure.

The Solution

1. RePlay may re-bond exposed aggregate BEFORE it gets loose. This can minimize raveling.
2. Lost material is already lost. Create a partial or full-depth patch using Activate and RAP. Apply RePlay over top to increase the bond.

Rutting


The Problem

Surface depressions in the wheel path.

There are two types of rutting: *mix* and *subgrade*.

Mix rutting appears as more obvious wheel path depressions. Subgrade rutting is where the pavement settles into an underlying subgrade rut. Ruts may not always be accidental stress, but also placed by design as a safety feature for drivers. Regardless, they are a pavement distress.

Rut edges can shear and uplift, spreading cracks and further damage. Ruts are particularly evident after rainfall when they fill with water.

The Solution

1. Shallow ruts: Can go untreated for a time. RePlay may temporarily strengthen shallow ruts, re-bond aggregate, and resist temperature cycling.
2. Deep ruts: Consider coating with Bio-Tak 4600, then a mix of Activate and RAP millings. Apply RePlay over patch area and adjacent asphalt.

Slippage Cracking

The Problem

Crescent or half-moon-shaped cracks, typically with two endpoints in the direction of traffic.

Slippage cracks are similar to shoving and corrugation. Tires will brake hard or turn in place, causing curved depressions or cracks in thin overlays and soft asphalt surfaces.This is often associated with an unbonded overlay or substrate (such as '90's era paving fabric)

The Solution

1. RePlay is a temporary fix. It will improve bond strength, shield against water, and resist thermal cycles and softening.
2. Replace damaged area with Activate and RAP patching. Apply RePlay for extra bond strength.

Stripping

The Problem

Deterioration or break in the bond between the aggregate and asphalt binder.

Stripping typically begins at the bottom of the asphalt layer and progresses upward. It can be a result of subgrade settlement, seepage and swelling, and tensile fatigue.

The Solution

1. Low-Severity Stripping: RePlay can seal hairline cracks, lessen water penetration, and re-bond asphalt aggregate. This may temporarily halt the progress of cracks.
2. High-Severity Stripping: Localized reconstruction is recommended. Remove the damaged sections. Apply a uniform coat of BioTak-4600, then insert a patch or overlay using Activate mixed with RAP millings.

Transverse Cracking

The Problem

Cracks that are perpendicular to the pavement's centerline or lay-down direction.

Transverse cracks cross perpendicular to the traffic lanes. Thermal stress is the common cause, where temperature cycling causes shrinkage and tear. The asphalt pavement is now no longer a continuously connected surface. Moisture will get inside that disconnect and speed up the freeze-thaw cycle distress.

The Solution

1. For low-severity cracks (less than one-quarter inch width), use a specified application of RePlay to seal those hairline cracks against moisture.
2. For high-severity cracks, remove and replace the cracked pavement layer with Activate mixed with RAP millings, then coat with RePlay.
3. Infra-Red can also be used to treat cracks when necessary.

Water Bleeding and Pumping

The Problem

The ejection of material caused by water seeping through joints or cracks caused by moving loads.

Damaged pavements can fill with water as it seeps or “bleeds” from cracks. Water may also bleed from subgrade swelling or high-water tables. Asphalt is flexible pavement and moves under traffic. Water is “pumped” from repeated traffic, and that water can eject material as well.

The Solution

1. High Water-tables: Remove driving surface, inspect subgrade, implement localized construction, improve drainage.
2. RePlay may be applied to limit the amount of water infiltration by filling voids.

Types Of Distress

Concrete pavements suffer from the same two basic categories of distress as asphalt: *load-associated* and *non-load-associated*. Concrete is a different material than asphalt because of its rigid, unyielding formation.

CONCRETE DISTRESS

The following section outlines common concrete distresses and the solutions from BioSpan:

C-Patch
Concrete Repair Agent
A fast-curing patch is used for all concrete damage. It provides a smooth transition between materials and is formulated to repair spalls, cracks, and holes. It will even bond to rebar and can be troweled to a smooth finish.

OptiSeal
Penetrating Concrete Preservation Agent
OptiSeal penetrates to stop moisture damage and stop the alkali-silica reaction (ASR) from spreading. It can even protect steel reinforcement from rusting to maintain concrete strength.

Alkali-Silica Reaction (ASR)

The Problem

A reaction within concrete caused by excessive moisture that leads to cracks and deterioration.

Reactive silica in certain aggregate and the alkalinity of cement can form a destructive “gel” when mixed with water. This expands and creates stress from within the concrete. Concrete without reinforcement will produce map cracking when undergoing ASR.

The Solution

1. Avoid using reactive aggregates in the concrete mix design phase.
2. Apply OptiSeal to stop ASR from spreading further. OptiSeal polymer technology can encapsulate aggregate and cement, while strengthening the matrix. OptiSeal penetrates concrete up to 10 times deeper than other sealants.
3. If damage is too far gone, consider reconstruction. Patching is temporary.

Blowup (Buckling)

The Problem

Expansion in concrete constructed with insufficient space to allow for thermal stress.

This localized, upward slab movement will shatter at a joint or crack. Blowups generally occur in spring or summer when weather causes expansion. Sometimes construction fails to install expansion joints.

Blowups are major failures that require reconstruction. The slab is usually cracked and broken. The underlying base is sometimes damaged. Patching or filling is only temporary.

The Solution

1. Low-severity: Apply C-Patch as a partial-depth replacement.
2. High-severity: Reconstruct slab

Corner Break

The Problem

Vertical cracks in a pavement that separate corners from the remaining slab.

Concrete slabs are rigid pads floating on subgrade rock or soil. If the underlying soil loses support, that floating slab fails under its own weight. Temperature cycling stress can also be a factor.

Cracks form along stress lines where the slab wants to bend. Corner breaks are 45-degree angle cracks breaking off a corner of the slab.

The Solution

1. Low-severity: OptiSeal may shield hairline cracks (1/4 inch and less) from further water seepage. OptiSeal polymers may also help bond. This is temporary for existing cracks.
2. High-Severity: C-Patch can work in larger cracks to temporarily bond the corners and slabs.

Durability Cracking (D-Cracking)

The Problem

Cracks near slab joints caused by freeze-thaw expansive pressures.

Tight-spaced, crescent-shaped cracks form near slab joints. They can form corner breaks or longer cracks. Freeze-thaw stress is the main culprit and traffic loading increases the stress.

The Solution

1. Low-Severity: OptiSeal may bond hairline cracks and prevent spread by shielding water penetration.
2. High-Severity: Partial or full-depth patching using C-Patch.

Edge Punch-Out (Edge rutting)

The Problem

Pieces of concrete punch downward into the subgrade due to heavy traffic loads and cracking.

Aggregate is lost between cracks, which causes support failure. The unsupported portion weighs itself down, spreading cracks. Traffic makes it worse and the eventual result is a rectangular punched section.

The Solution

1. Apply OptiSeal early to stop hairline crack progression.
2. Low-Severity: C-Patch can work as partial depth bonding.
3. High-Severity: Larger punchouts may need slab reconstruction

Faulting (Transverse Joints / Cracks)

The Problem

A difference in elevation between joints or cracks perpendicular to the direction of traffic.

Adjacent concrete slabs have a difference in elevation. This usually happens when slab joints don’t have dowel rods to transfer stress. Generally, the approach slab (further) is lifted higher than the leave slab (closer) as traffic passes overhead.

The Solution

1. 1/4 and 1/2 inch: Dowel rod maintenance or construction is recommended. C-Patch can work as a patch material afterwards.
2. Diamond milling to restore ride quality
3. Greater than 1/2 inch: Full slab reconstruction may be in order.

Joint Load Transfer Deterioration


The Problem

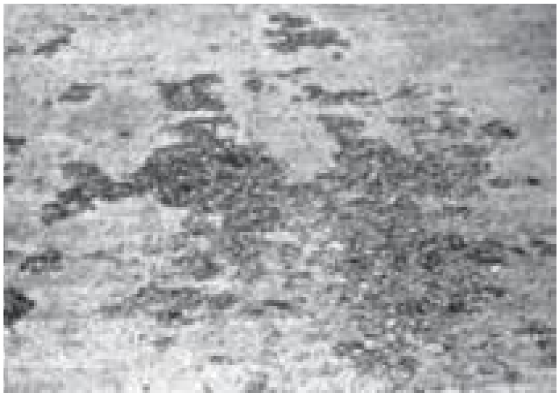
Cracking appears close to a slab joint that affects the dowel transfer system between slabs.

Traffic (and freeze-thaw) damages the joints between concrete slabs. Material can wear away and damage the structure. This can lead to D-Cracks, Corner breaks, transverse cracking, and faulting. Dowel rods should be inspected and possibly replaced, along with reconstruction depending on severity.

The Solution

1. OptiSeal may bond hairline cracks and shield against water penetration.
2. Larger cracks may benefit from C-Patch.

Map Cracking / Scaling / Crazing

The Problem

Multiple hairline cracks appearing on the surface that stem from ASR, traffic, thermal stress, or maintenance treatments.

A multitude of hairline cracks that look like a road map. Alkali-Silica Reaction (ASR), freeze-thaw, traffic, shallow rebar all can cause map cracking.

Scaling and crazing look more like pock marks, from de-icing salts eating away the concrete surface.

The Solution

1. Low-severity: OptiSeal may seal hairline cracks and prevent moisture penetration. OptiSeal can protect reinforcing steel from rusting. OptiSeal can also improve resistance to deicing salts.
2. High-severity: Reconstruction is warranted. Map cracks cause structural failure because the concrete has now lost a bulk of its integrity.

Spalling (Corner)

The Problem

Raveling or breakdown of concrete near corners.

Aggregate breaks down, ravels, and wears away. The slab degrades in a downward angle into the pavement, rather than snapping like a corner break. Traffic and weather will worsen conditions.

The Solution

1. Low-severity: OptiSeal may seal hairline cracks and prevent moisture penetration, improving resistance to freeze-thawing. OptiSeal can protect reinforcing steel from rusting
2. High-Severity: Consider partial or full depth replacement of the damaged area using C-Patch to replace lost material and structure.

Spalling (Transverse / Longitudinal)

The Problem

Cracking, breaking, or chipping of joint edges or other distress cracks.

Spalling usually occurs within a couple feet of a joint or crack. Spalling usually intersects joints or other cracks at angles. Spalling is common in weak concrete pavements that have poor load transfer. Incompressible materials may even slip in between joints and propagate cracks.

The Solution

1. Low-Severity Cracking: Apply OptiSeal to seal hairline cracks and provide a temporary polymer-strengthening bond. This will help shield against further water damage.
2. High-Severity Cracking: Consider partial-depth or full-depth patching; dig up the affected area and patch with C-Patch.

BioSpan Solutions

Biospan products are designed to save time, labor and money using non-toxic, biobased technologies. Aside from pavement distress maintenance, below are some other biobased solutions available through BioSpan Technologies, Inc.

Asphalt Solutions

A-Patch
Asphalt Crack Filler

Activate
Asphalt Millings Restorer

Activate Cleaner
Equipment Cleaner For Activate

AR-3600
Asphalt and Tar Remover

AR-C
Asphalt and Tar Remover

BioTak-4600
BioBased Tack Coat

BR-3600
Bed Release Agent

BST Cleaner
BioSpan Spray System Cleaner

CR-3600
Corrosion Protectant

RePlay
Agricultural Oil Seal & Preservation Agent

RePlay+
Tinted Version of RePlay

SeamSeal
Biobased Seal for Asphalt Joints and Seams

Concrete Solutions

BNew
Brick and Stone Cleaner

C-Cure
Concrete Curing Agent

C-New
Concrete Cleaner and Degreaser

C-Patch
Concrete Repair Agent

CapTec-5500
Concrete Roof Tile Protection

FR-4400
Forms Release Agent

FSR-4450
Form Spacer Remover

OptiSeal
Penetrating Concrete Sealer

Dust Control Solutions

DeDust
Dust Control Agent

EnCap-3600
Dust Control Agent

Specialty Solutions

A+ Clean
Alkaline Cleaner Concentrate

C-Clear
Glass Cleaner

EC-3600
Enzyme Detergent for Porous Pavements

First Choice
Multi-Surface Cleaner

GR-3600
Graffiti Remover

HC-3600
Waterless Hand Cleaner

MG Degreaser Cleaner
Heavy-duty Degreasing

NeutraClean
General Surface Cleaning

VetraClean
Polished Surface Restoration

About Biospan Technologies

BioSpan Technologies, Incorporated, is a leader in green pavement management technology. Through innovative concepts and patented nano polymer chemistry, BioSpan develops solutions that work under the most demanding actual use conditions that stand the test of time. Our products excel when most other products fail!

Learn more about the full pavement solutions product line at biospantech.com.