Full-Depth Reclamation With Cement: The Road Recycled

A publication from the Portland Cement Association

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Deteriorating roads are a constant problem for cities and counties. That’s why engineers and public works officials are turning to a process called full-depth reclamation (FDR) with cement. This process rebuilds worn out asphalt pavements by recycling the existing roadway. The old asphalt and base materials are pulverized, mixed with cement and water, and compacted to produce a strong, durable base for either an asphalt or concrete surface. FDR uses the old asphalt and base material for the new roadway base. There’s no need to haul in aggregate or haul out old material for disposal. Truck traffic is greatly reduced, and there is little or no waste.

FDR recycles the materials from deteriorated asphalt pavement, and, with the addition of cement, creates a new stabilized base. A surface consisting of a thin bituminous chip seal, hot-mix asphalt, or concrete completes the rebuilt road. The recycled base will be stronger, more uniform, and more moisture resistant than the original base, resulting in a long, low-maintenance life. And most important, recycling costs are normally 25 to 50 percent less than removal and replacement of the old pavement.

Material Conservation: A Wise Choice

FDR with cement conserves virgin construction materials and makes smart economic and strategic sense. A century of modern growth and urbanization in America has depleted once plentiful aggregate supplies. Frequently, aggregates either come from distant quarries at great expense or from local sources offering only marginal quality. Continuing to exhaust these valuable resources to rebuild existing roads only propagates and accelerates the problem. Additionally, if old asphalt and base materials are not recycled, they must be disposed of or stockpiled, increasing transportation costs and utilizing valuable landfill space. In some locales, old asphalt can no longer be landfilled. Environmental laws are becoming stricter, thus adding to the
expense of mining new materials and landfi lling old.

FDR with cement makes the re-construction of old roads a largely self-sustaining process. The original “investment” in virgin road materials becomes a one-time cost, which is reclaimed through cement stabilization and the addition of a new, thin surface course.

Design and Construction: Simple and Fast

The basic procedure is simple. The complete recycling process can be finished in one day, and traffic can be maintained throughout construction. The procedure includes the following steps:

Site Investigation
The site should be investigated to determine the cause of failure. Core samples or test holes should be used to determine layer thicknesses and to obtain samples of the material to be recycled. Material sampling should include the asphalt surface, base course aggregate, and subgrade soil.

Thickness Design
Pavement thickness can be determined by using Portland Cement Association’s Thickness Design for Soil-Cement Pavements. Other methods, such as the American Association of State Highway and Transportation Officials’ Guide for Design of Pavement Structures can also be used.

Laboratory Evaluation
Material samples from the site should be pulverized in the laboratory to create an aggregate-soil mix that will be similar to that expected from the reclamation process. The mix design procedure is the same as that performed for soil-cement. This includes the determination of maximum dry density and optimum moisture content. If unconfined compressive strength is used to determine cement content, a 7-day strength of 300 to 400 psi (2.1 to 2.8 MPa) is recommended.

Pulverization
Construction begins with pulverizing the existing asphalt pavement using equipment that resembles a large rototiller. (This pulverizing/mixing equipment is also commonly used to mix cement with soils when stabilizing pavement subgrades.) The depth of pulverization is usually 6 to 10 inches (150 to 250 mm), which on secondary roads will typically include all of the surface and base, plus some part of the subgrade. To achieve the proper
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gradation after pulverization, more than one pass of the equipment may be necessary. The particle distribution should be such that 100 percent passes the 3-inch (75-mm) sieve, 95 percent passes the 2-inch (50-mm) sieve, and at least 55 percent passes a No. 4 (4.75-mm) sieve.

Shaping and Grading
The pulverized material is shaped to the desired cross-section and grade. This could involve additional earthwork in order to widen the roadway. Final base elevation requirements may necessitate a small amount of material removal or addition.

Spreading Cement
A measured amount of cement is spread either in dry or slurry form on the surface of the shaped roadway.

Water Application
Water is added to bring the aggregate-soil-cement mixture to optimum moisture content (water content at maximum dry density as determined by ASTM D558). When the pulverized material is very dry (well below optimum moisture content) an initial application of water is normally added and mixed into the pulverized material prior to spreading the cement.

Mixing
The aggregate-soil-cement-water mixture is combined and blended with the pulverizing/mixing machinery. More than one pass of the mixer may be required to achieve a uniform blend of materials.

Compaction
The mixture is compacted to the required density of at least 96 percent of standard Proctor density (ASTM D558). The compaction is usually performed with vibratory rollers. A pneumatic-tired roller may follow to finish the surface. Final compaction should take place no more than two hours after initial mixing of the cement. The field density and moisture are monitored for quality control purposes.

Curing
The goal of curing is to keep the base continuously moist so the cement can hydrate. The completed
base should be coated with bituminous primer to seal in the moisture. Another method of curing is to keep the base constantly moist by spraying water on the surface.

Pavement Surface
The new pavement surface consisting of a chip seal, hot-mix asphalt, or concrete is constructed to complete the FDR process.

Quality Control
FDR with cement follows the same basic procedures used for normal soil-cement operations. The success of a reclamation project depends upon careful attention to the following control factors:

- Adequate pulverization
- Proper cement content
- Proper moisture content
- Adequate density
- Adequate curing
Rehabilitating Pavement

What Roads Are Candidates For Full-Depth Reclamation?

When asphalt pavements fail, determining the best rehabilitation procedure can be difficult. A simple asphalt overlay or a “mill and fill” approach can improve the appearance of the pavement surface, but may do little to correct the underlying problems that caused the failure in the first place. Within a short period of time the problems will likely reappear.

Long-term solutions to failed asphalt pavements include a thick structural overlay or complete removal and replacement of the existing base and asphalt surface. Both methods can be very expensive and wasteful of virgin aggregates.

A third choice, recycling the failed asphalt pavement through a process called “full-depth reclamation” (FDR) using portland cement, can provide the benefits of reconstruction without the substantial costs and environmental concerns. This procedure pulverizes the existing asphalt and blends it with underlying base, subbase, and/or subgrade materials, which are mixed with cement and compacted to provide a new stabilized base. A new surface is then applied, which completes the FDR process, providing a new roadway structure using recycled materials from the failed pavement. Because of...
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cement stabilization, the new base will be more uniform, stronger, and provide better long-term performance than the original pavement.

The cost advantages of recycling materials from the original pavement are obvious; however, there are other environmental advantages that are important to the FDR process:

- Conservation of new aggregates that must be quarried and transported to the site.
- Conservation of land areas that would be used to dispose of the asphalt and base materials from the failed pavement.
- Reduced air pollution, traffic congestion, and damage of nearby roadways resulting from hauling new materials to the site, and disposal of old materials.

**Determining When FDR Is Appropriate**

FDR is most appropriate under the following conditions:

- The pavement is seriously damaged and cannot be rehabilitated with simple resurfacing.
- The existing pavement distress indicates that the problem likely exists in the base or subgrade.
- The existing pavement distress requires full-depth patching over more than 15 to 20 percent of the surface area.
- The pavement structure is inadequate for the current or future traffic.

**Serious Damage or Base Failure**

An engineer can evaluate the reasons for pavement failure by observing the types of distress that are visible. For example, alligator cracking, deep depressions, or soil stains on the surface are all signs of base or subgrade problems in the pavement structure.

**Excessive Patching**

Although patching is often necessary to keep a road serviceable, it can be expensive. In fact, once the area of full-depth patching exceeds 15 to 20 percent, simple math proves it less expensive to use FDR than to perform the patching. Of course, the final product achieved with FDR is far superior to a road that is severely patched.

**Inadequate Pavement Structure**

Often the traffic patterns on a road will change throughout the years. This sometimes results in roads that were originally constructed for light traffic but are now significantly under-designed for existing and future traffic loads. When this happens, often a road is “built-up” by increasing the thickness of the existing pavement structure. However, increasing the pavement thickness also requires building up and extending the shoulders, since a reasonable shoulder slope needs to be maintained for safety. This can require significantly more right-of-way. An alternative exists with FDR, where the pavement can be strengthened by “building the pavement down.” By reclaiming the existing pavement into a stabilized base, the road is strengthened without the requirement of more right-of-way.

**Special Considerations When Using FDR**

Because the pulverized asphalt from the existing pavement (called “reclaimed asphalt pavement,” or RAP) is blended with the underlying base materials, the thickness of reclaimed asphalt cannot exceed the depth of reclamation for an extended length (short sections of full-depth asphalt, like a patch, are allowed). If a long section of thick asphalt is selected for reclamation, the asphalt layer can be partially milled and the RAP stockpiled for future use. The remaining asphalt in the old pavement is then reclaimed and blended with the base.

Another consideration when evaluating FDR is the existence of large rocks (larger than 4 inches (100 mm) in diameter) in the base or subgrade. If this material is within the depth of reclamation, the costs of reclaiming may be high because the contractor must take into consideration the slower and more difficult construction that is posed by the rocks.
Soil-cement was first used in 1935 to improve the roadbed for State Highway 41 near Johnsonville, South Carolina. Since that time, portland cement has been used to stabilize soils and aggregates for pavement applications on thousands of miles of roadway throughout the world.

After more than 70 years, collective experience has demonstrated that different kinds of soil-cement mixtures can be tailored to specific pavement applications. However, the basics always remain the same: soil-cement is the simple product of portland cement blended with soil and/or aggregate, and water and compacted for use in a pavement structure. There is no secret ingredient or proprietary formula that makes soil-cement work. Although sharing a similar chemical process, soil-cement differs from conventional portland cement concrete in the consistency of the material, quantity of cement required, overall construction procedures, function and strength requirements.

Conventional concrete has a higher cement content and higher water content to form a paste that coats all the aggregates. With soil-cement, not all the soil particles are coated with a cement paste. The water content in soil-cement is determined from geotechnical engineering tests to find the best moisture level for compaction. The amount of cement used in soil-cement is generally insufficient to create a durable wearing surface, so soil-cement is surfaced with concrete or bituminous products. Flowable fill is a controlled low-strength material often used as backfill material.

Similar to soil-cement, a durable pavement surface is required. A material that needs no wearing surface and is as strong as conventional concrete, but constructed similar to soil-cement, is roller-compacted concrete (RCC). RCC achieves its high strength because of a higher cement content and the use of properly selected and graded aggregate.

Four major variables control the properties and characteristics of soil-cement: (1) the nature of the soil material — whether it’s clay, silt, sand, coarse aggregate, or a combination; (2) the proportion of cement in the mix; (3) moisture conditions, such as the moisture content of mix at the time of compaction and curing conditions (moisture, temperature and time); and (4) the degree of compaction. It is possible, simply by varying the cement content, to produce mixes ranging from those that result in only modification of the compacted soil to those which result in hard soil-cement that will meet durability and strength requirements.

Soil Cement Products

Soil-cement is an engineered material designed and constructed for various pavement applications or material characteristics. The best soil-cement product is the one best suited to the specific application.
Water and cement is mixed with soil.

Cement-Modified Soil (CMS)

Many problems can occur during construction when silt and clay soils are encountered, particularly when they are wet. These soils can be soft, plastic, and difficult to compact. Cement-modified soil (CMS) is used to improve the engineering properties and construction characteristics of silt and clay soils by reducing the plasticity and enhancing the compaction and strength of the material. With 3 to 5 percent (by dry weight) of cement used to modify the soil, the final product is an improved construction material.

Principal Benefits of CMS:
- Improved constructability of marginal on-site soils
- Reduced plasticity and improved strength
- Less susceptible to damaging effect of water
- An all-weather work platform
- Use of on-site soil rather than removal and replacement with expensive select fill material
- Permanent soil modification (does not leach)
- No mellowing period required

Cement-Treated Base (CTB)

Cement-treated base is a general term that applies to all hardened soil-cement that meets the project specified minimum durability and strength requirements. The soil-cement can be mixed-in-place (like CMS) using on-site soils or mixed in a central plant using selected aggregate. However, CTB uses more cement than CMS, resulting in a strong, durable, frost resistant layer for the pavement structure. Typical cement contents range from 3 to 10 percent cement, resulting in 7-day unconfined compressive strengths from 300 – 800 psi (2.1 – 5.5 MPa).

The mixed-in-place construction process consists of the following steps:
- Initial shaping and grading
- Application of cement
- Mixing water and cement with soil
- Compaction and fine grading
- Curing

Cement-treated base can also be produced in a central plant or pugmill using a selected aggregate. The mixed CTB is hauled to the placement area in dump trucks and placed on the roadway using a grader, paver or Jersey-type spreader.

Full-Depth Reclamation (FDR)

A special case of cement-treated base is full-depth reclamation, where aggregate for the cement-stabilized base is obtained by pulverizing and recycling the old asphalt surface and base material. This construction procedure is very similar to mixed-in-place construction, except that there is an aggregate specification for the blend of the pulverized asphalt and old base material. FDR commonly uses 4 to 6 percent cement and results in 300 – 400 psi (2.1 – 2.8 MPa) unconfined compressive strengths in 7 days.
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The Asphalt Recycling & Reclaiming Association Responds to Need for Stronger, Safer Highways and Roads

The Asphalt Recycling & Reclaiming Association (ARRA) is an international non-profit trade association of contractors, equipment manufacturers, suppliers, public officials, and engineers engaged in the recycling and reclaiming of asphalt, using the positive economies of recycling to rebuild a stronger and safer network of highways, streets and roads across the country and around the world.

ARRA members are an integral part of the continuing effort for system preservation and rehabilitation to provide a safe, cost-efficient, and comprehensive network of roads and highways. The asphalt recycling and reclaiming industry is a strong, healthy component of the highway maintenance, rehabilitation, and preservation market. Public agencies are stretching their dollars by paying increased attention to the benefits of recycling, and reclaiming their existing asphalt pavements. Environmentalists, taxpayers and legislators will be pleased to know that ARRA member contractors are responsible for keeping literally millions of tons of asphalt out of North American landfills.

A cornerstone of ARRA’s efforts to increase the market share for recycled asphalt has been its work through local organizations, universities, and technology transfer centers to conduct seminars to educate those involved in the design, construction and maintenance of streets, roads and highways on the merits of asphalt recycling and reclamation.

ARRA continues to take steps to increase its visibility on federal, state, and local levels. The association is actively involved with the Federal Highway Administration (FHWA), the Foundation for Pavement Preservation (FP2), and the new National Center for Pavement Preservation. ARRA officials in the past year have met with FHWA officials and highway industry association executives to keep the association attuned to what is going on at the federal level. ARRA’s membership in the American Highway Users Association, the Transportation Construction Coalition, and The Road Information Program (TRIP) – three of the main forces behind the passage of TEA 21 and institutional leaders in making sure that TEA 21 funds are spent on the highways – provides the association with key contacts.

The Asphalt Recycling & Reclaiming Association serves as an excellent network for the information exchange and technology transfer among professionals in the highway industry. Although the association does not maintain a technical staff, it addresses a surprisingly large volume of inquiries through the Frequently Asked Questions section of its Web site at www.arra.org. In addition, questions are e-mailed to the headquarters office and then distributed to various member experts to formulate a timely, non-biased response. ARRA prides itself on being able to address concerns of a technical nature by calling upon the tremendous bank of expertise that exists throughout its membership. Time and again, persons call ARRA headquarters after receiving little useful assistance from other sources and are thrilled to be referred to a resource that can answer their questions.

ARRA is also a forum for the exchange of ideas and solutions to recycling concerns. In addition, ARRA plans to develop new programs, strategies and funding not only to improve the technological side of the industry but also to increase the market share for recycled asphalt, as compared to other types of maintenance, preservation, and rehabilitation options.
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FULL-DEPTH RECLAMATION

Full-Depth Reclamation with cement, or FDR, uses the old asphalt and underlying base material to build a new road. The existing pavement is pulverized, mixed with cement and water, and compacted to produce a strong, durable base for surfacing.

Existing materials are recycled on site. There’s no need to haul in new aggregate or haul out old materials for disposal. FDR conserves natural resources, saves energy, and reduces waste.

A stronger base means longer life. Stronger than an unstabilized base, a cement-stabilized base keeps water out and stands up to heavy, constantly increasing traffic loads, reducing maintenance and prolonging pavement life.

Recycling saves money. FDR with cement costs up to 50% less than removal and replacement of the old pavement or thick overlays.

To find out more, visit our Web site at www.cement.org/FDR