Soil-Cement Technology for Pavements: Different Products for Different Applications

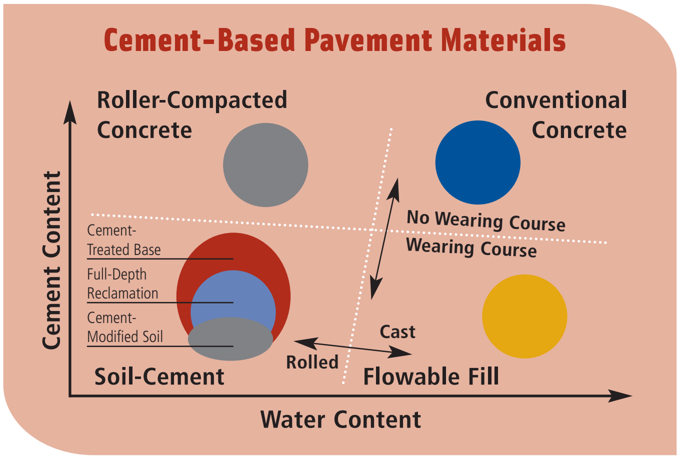
What is Soil-Cement?

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 all over 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.

The figure in the adjoining column illustrates how soil-cement compares to other cement-based pavement materials. 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 which result in only modification of the compacted soil to those which result in hard soil-cement that will meet durability and strength requirements.



Different 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.

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 – 5% (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

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Initial shaping and grading.

Application of cement.

Mixing water and cement with soil.

Compaction.

- 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 – 10% 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.

Recycling old asphalt pavement using FDR.

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 – 6% cement and results in 300 – 400 psi (2.1 – 2.8 MPa) unconfined compressive strengths in 7 days.

How Does Soil-Cement Benefit Pavement Structure?

Distributes Loads. A cement-stabilized base will be much stronger and more rigid than an unstabilized granular base. This higher stiffness of the cement-treated base will act to distribute loads over a wider area, reducing the stresses on the subgrade and acting as the load carrying element of a flexible pavement or a subbase for concrete.

Eliminates Rutting in Base. Rutting will not occur in a cement-treated base. If rutting occurs in a granular base, or the subgrade, a simple overlay of the pavement surface cannot fix the problem that led to the rutting in the first place. With a cement-treated base, rutting is confined to the asphalt surface layer and is relatively simple to correct. A cement-treated base will keep rutting from occurring deep in the pavement where it is extremely difficult to repair.

Reduces Moisture Problems. Cement-treated bases are designed to be virtually impermeable. This keeps water out of the base, so that even under frost conditions no ice lenses can form in the base layer. With a granular material, if poor drainage exists or groundwater rises, the base can easily become saturated. When this happens with an unbound material, significant strength losses occur. The cement-stabilized layer, being a bound material, will maintain significant strength even in the unlikely event it becomes saturated.

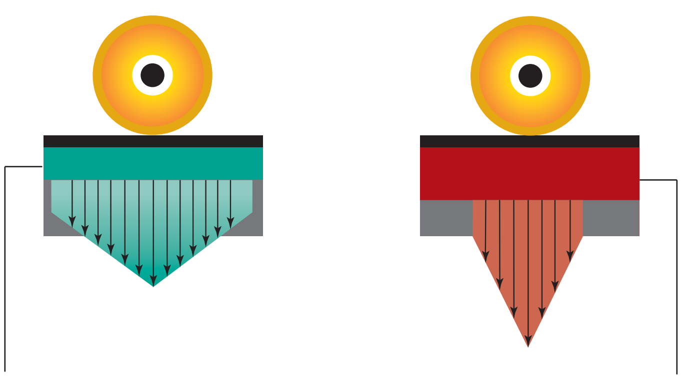
Reduces Deflection. The higher stiffness of cement-treated bases will lead to lower pavement deflections and lower asphalt strains. This will result in longer fatigue life for the asphalt surface as compared to an asphalt pavement with a granular base, which will have higher deflections and strains.

How Does Cement Compare with Other Stabilizing Agents?

Cement provides more strength and is far more versatile than any other stabilizing agent. Versatility is extremely important, since site and roadway conditions can easily change during or between projects. Cement can provide a long-lasting, strong, high-performing stabilizer for a wide range of site conditions and materials (from gravels to clays). This is not true for other stabilizers, which will only work under certain conditions.

Stabilized Base vs. Unstabilized Base

A stabilized base spreads loads and reduces stress on the subgrade.



Cement-Stabilized Base   Unstabilized Granular Base

> ***"Portland cement is probably the closest thing we have to a universal stabilizer."***
>
> United States Army Corps of Engineers
> *Chemical Stabilization Technology for Cold Weather, September 2002*

Soil-Cement Products

	Cement-Modified Soil (CMS)	Cement-Treated Base (CTB)	Full-Depth Reclamation (FDR)
Purpose:	Improves workability and construction of subgrade soils, reduces Plasticity Index, improves bearing strength, and provides an excellent construction platform	Provides strong, frost resistant base layer for asphalt or concrete pavements	Provides strong, frost resistant base layer for asphalt or concrete pavements
Materials:	Cohesive soils, silt/clay/sand mixtures 3 – 5% cement added	Natural soil mixtures, gravel/sand/silt/clay. Also aggregates or aggregate/soil blends 4 – 10% cement (mixed in place) 3 – 6% cement (plant mixed)	Pulverized asphalt blended with old pavement base, subbase, and/or subgrade Meets aggregate gradation limits 4 – 6% cement added
Construction Practices:	Minimum 95 - 98% of maximum density Mixed in place	Minimum 95 - 98% of maximum density 300 – 800 psi (2.1 – 5.5 MPa) compressive strength (7 days) Mixed in place or plant mixed	Minimum 95 - 98% of maximum density 300 – 400 psi (2.1 - 2.8 MPa) compressive strength (7 days) Typically mixed in place

Soil-Cement Materials in Pavement Section

More Information

PCA offers broad range of resources on soil-cement applications for pavements. Visit our Web site at **www.cement.org/pavements** for design and construction guidelines, technical support, and research on cement-modified soils, cement-treated base, and full-depth reclamation.

For local support, tap into the cement industry's network of regional groups covering the United States. Contact information is available at **www.cement.org/local.**

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An organization of cement companies to improve and extend the uses of portland cement and concrete through market development, engineering, research, education, and public affairs work.

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