Track 12. Advanced Concrete Pavement Materials (AM)

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Track 12 (AM) Overview

If the concrete pavement industry continues to use the same types of materials, the same problems and limitations will persist in concrete pavement applications. Fortunately, innovative concrete paving materials are continually being developed to enhance performance, improve construction, and reduce waste. The problem statements in this track will develop new materials and refine or introduce existing advanced materials. Many existing materials that the problem statements study have only been used thus far on a small scale, such as in laboratory tests. Most existing materials have not been used in the United States, but have been used successfully in other countries. This track will bring new concrete paving materials into common practice by experimenting with them on a larger scale and developing standards and recommendations for their use. Moreover, this research will foster innovation in the development of new and innovative concrete pavement materials.

The problem statements in this track are grouped into three subtracks: performance-enhancing, construction-enhancing, and environment-enhancing concrete pavement materials. Performance-enhancing materials will improve pavement durability and long-term performance, perhaps extending pavement life further than conventional materials. Construction-enhancing materials will improve the construction process by reducing material requirements, labor requirements, or construction time. Finally, environment-enhancing materials show promise not only by reducing waste through pavement reclamation, but also for reducing raw consumer and industrial waste. Clearly, many of these materials fit in more than one category. A material that improves the construction process, for example, may also improve pavement durability and performance. Likewise, a material that uses consumer waste may also improve pavement performance.

The emphasis on environment-enhancing materials is significant. Not only are contractors and agencies paying heavily to dispose of reclaimed asphalt and concrete pavement, but other industries are looking for environmentally responsible ways to dispose of industrial and consumer waste to reduce the burden on landfills. Environmental concerns are expected to become more important in the next few decades as landfills quickly fill.

The following introductory material summarizes the goal and objectives for this track and the gaps and challenges for its research program. A chart is included to show an overview of the subtracks and problem statements in the track. A table of estimated costs provides the projected cost range for each problem statement, depending on the research priorities and scope determined in implementation. The problem statements, grouped into subtracks, then follow.

Track Goal

New materials will be evaluated and existing materials will be refined to improve concrete pavement performance, enhance construction, and lessen environmental impact.

Track Objectives

1. Improve pavement durability and long-term performance to extend pavement life further than conventional materials.

2. Improve the construction process by reducing material requirements, labor requirements, or construction time.

3. Reduce waste through pavement reclamation.

Research Gaps

- Lack of understanding of how advanced materials impact concrete pavement performance, construction, and the environment.

- Limited full-scale testing of new and innovative materials.

Research Challenges

- Experiment with advance concrete pavement materials on a larger scale than previously done.

- Developing standards and recommendations for the use of advanced concrete pavement materials.

- Foster innovation in the development of new and innovative concrete pavement materials.

Research Track 12 (AM) Phasing

Subtrack	Subtrack Name	Unphased
Subtrack AM 1	Performance-Enhancing Concrete Pavement Materials	AM 1.1. Flexible Cementitious Overlay Materials
		AM 1.2. High-Performance, Fiber-Reinforced Concrete Pavements
		AM 1.3. Pervious Concrete Pavement Program
		AM 1.4. Carbon Dioxide Treated Materials
		AM 1.5. Reactive Powder Concretes as Ductile Materials
		AM 1.6. Chemically Bonded Ceramic (Ceramicrete)
		AM 1.7. Localized High-Quality Concrete at the Joints
		AM 1.8. Alternative Reinforcement Material for Continuously Reinforced Concrete Pavements
Subtrack AM 2	Construction-Enhancing Concrete Pavement Materials	AM 2.1. Application of Self-Consolidating Concrete for Concrete Paving
		AM 2.2. Applying Very High Strength Concrete to Pavement Operations
		AM 2.3. Dry-Laid Concrete
		AM 2.4. Energetically Modified Cement
		AM 2.5. Advanced Curing Materials
		AM 2.6. Cold Weather Concreting Advancements
		AM 2.7. Advancements in Internal Curing of Concrete
		AM 2.8. Self-Curing Concrete
Subtrack AM 3	Environment-Enhancing Concrete Pavement Materials	AM 3.1. Cement Containing Titanium Dioxide
		AM 3.2. Sulfur Concrete
		AM 3.3. Increased Percentages of Reclaimed Asphalt Pavement as an Aggregate for Concrete Paving Mixtures
		AM 3.4. Mix Design Considerations with Recycled Concrete Aggregate
		AM 3.5. Acceptance Criteria for Using Recycled Aggregate
		3.6. Waste Materials in Concrete Mixes
		AM 3.7. Ecocement for Concrete Mixes
		AM 3.8. Polymer Concrete Made from Recycled Plastic Bottles

Research Track 12 (AM) Estimated Costs

Problem Statement	Estimated Cost
Subtrack AM 1. Performance-Enhancing Concrete Pavement Materials	
AM 1.1. Flexible Cementitious Overlay Materials	$500k–$1M
AM 1.2. High-Performance, Fiber-Reinforced Concrete Pavements	$1M–$2M
AM 1.3. Pervious Concrete Pavement Program	$500k–$1M
AM 1.4. Carbon Dioxide Treated Materials	$100k–$250k
AM 1.5. Reactive Powder Concretes as Ductile Materials	$500k–$1M
AM 1.6. Chemically Bonded Ceramic (Ceramicrete)	$100k–$250k
AM 1.7. Localized High-Quality Concrete at the Joints	$1M–$2M
AM 1.8. Alternative Reinforcement Material for Continuously Reinforced Concrete Pavements	$500k–$1M
Subtrack AM 2. Construction-Enhancing Concrete Pavement Materials	
AM 2.1. Application of Self-Consolidating Concrete for Concrete Paving	$500k–$1M
AM 2.2. Applying Very High Strength Concrete to Pavement Operations	$1M–$2M
AM 2.3. Dry-Laid Concrete	$500k–$1M
AM 2.4. Energetically Modified Cement	$100k–$250k
AM 2.5. Advanced Curing Materials	$250k–$500k
AM 2.6. Cold Weather Concreting Advancements	$500k–$1M
AM 2.7. Advancements in Internal Curing of Concrete	$250k–$500k
AM 2.8. Self-Curing Concrete	$250k–$500k
Subtrack AM 3. Environment-Enhancing Concrete Pavement Materials	
AM 3.1. Cement Containing Titanium Dioxide	$100k–$250k
AM 3.2. Sulfur Concrete	$100k–$250k
AM 3.3. Increased Percentages of Reclaimed Asphalt Pavement as an Aggregate for Concrete Paving Mixtures	$1M–$2M
AM 3.4. Mix Design Considerations with Recycled Concrete Aggregate	$1M–$2M
AM 3.5. Acceptance Criteria for using Recycled Aggregate	$500k–$1M
AM 3.6. Waste Materials in Concrete Mixes	$1M-2M
AM 3.7. Ecocement for Concrete Mixes	$100k-250k
AM 3.8. Polymer Concrete Made from Recycled Plastic Bottles	$100k-250k
Track 12 (AM)	
Total	$11.45M–$23.25

Track Organization: Subtracks and Problem Statements

Track 12 (AM) problem statements are grouped into three subtracks:

- Subtrack AM 1. Performance-Enhancing Concrete Pavement Materials
- Subtrack AM 2. Construction-Enhancing Concrete Pavement Materials

- Subtrack AM 3. Environment-Enhancing Concrete Pavement Materials

Each subtrack is introduced by a brief summary of the subtrack's focus and a table listing the titles, estimated costs, products, and benefits of each problem statement in the subtrack. The problem statements then follow.

Subtrack AM 1. Performance-Enhancing Concrete Pavement Materials

The innovative materials developed in this subtrack may meet requirements that conventional concretes do not meet as efficiently. The materials developed are specialty concrete varieties for specific, unique applications.

Problem Statement	Estimated Cost	Products	Benefits
AM 1.1. Flexible Cementitious Overlay Materials	$500k–$1M	Specifications, design criteria, and construction procedures for flexible cementitious overlays.	New, more durable overlay material that is not as susceptible to rutting and shoving as asphalt and can be placed in thin, flexible layers.
AM 1.2. High-Performance, Fiber-Reinforced Concrete Pavements	$1M–$2M	Design recommendations, construction procedures, and specifications for fiber-reinforced concrete pavement.	Fiber-reinforcement that will result in high-performance concrete pavement that is less susceptible to microcracking from concrete shrinkage than other pavements, resulting in a more durable, long-lasting pavement.
AM 1.3. Pervious Concrete Pavement Program	$500k–$1M	Design recommendations, construction procedures, and specifications for pervious concrete pavement for highway pavements.	Pervious concrete pavements that will drain water from the pavement surface without the need for a cross slope, improving the safety of the pavement surface; promotion of the breakdown of chemical pollutants due to the large surface area within the pavement surface.
AM 1.4. Carbon Dioxide Treated Materials	$100k–$250k	Recommendations for using carbon dioxide treated materials for concrete pavements.	Carbon dioxide treated materials that will increase strength and the rate of strength development, while significantly decreasing permeability, resulting in more durable pavements that can be opened to traffic faster.
AM 1.5. Reactive Powder Concretes as Ductile Materials	$500k–$1M	Design and material recommendations and construction procedures for using reactive powder concrete (RPC) for ultra-high-performance concrete pavements.	Ultra-high-performance concretes using RPC that are very high-strength concretes with ductility and very low permeability; the possibility of thinner pavement sections and a reduction or elimination of reinforcement, resulting in a more durable pavement that is cheaper to construct.
AM 1.6. Chemically Bonded Ceramic (Ceramicrete)	$100k–$250k	Recommendations for using Ceramicrete in concrete paving applications.	Better corrosion resistance and strength characteristics for concrete pavements, resulting from Ceramicrete's very low permeability and higher compressive strength than normal-strength concrete.

AM 1.7. Localized High-Quality Concrete at the Joints	$1M–$2M	Recommendations for using high-quality materials at the joints in concrete pavements.	High-quality material at the joint regions in concrete pavements that may not be affordable for use in the rest of the slab, ensuring better joint toughness and durability and enhancing pavement life.
AM 1.8. Alternative Reinforcement Material for Continuously Reinforced Concrete Pavements	$500k–$1M	Recommendations for alternative reinforcing materials for CRCP.	Alternative reinforcing materials that provide better corrosion resistance, bond strength, and modulus of elasticity; lighter materials that reduce labor costs during placement and dependence upon a volatile steel market.

Problem Statement AM 1.1. Flexible Cementitious Overlay Materials

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 1. Performance-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $500k–$1M

The majority of hot-mix asphalt pavements will ultimately fail due to rutting. Increased axle loads, higher tire pressures, and increasing traffic volume contribute to this problem, leading to the situation today, where more than 90 percent of roads are being overloaded. The development of a cementitious overlay material that can be used as a strengthening and wearing course on flexible pavements, even when applied in thin layers, would thus be extremely useful. Ductility of the material is obtained through controlled microcracking and fiber reinforcement. A major project is currently underway in the European community to look at porous polymer concretes. Several different compositions such as this could be used, resulting in the selection of a few types to be used for full-scale testing as overlays on appropriate highways. A similar project could be conducted in the United States that builds off of the information and results from the European community project. Design criteria and draft specifications for the use of the new material will be a part of the project results.

Tasks:

1. Identify required properties for thin overlays.
2. Identify existing materials used for thin cementitious overlays.
3. Modify existing materials or develop new materials for thin overlays, if necessary.
4. Develop field trials or accelerated load testing of overlay materials.
5. Develop design criteria, specifications, and construction procedures for use of cementitious overlay materials.

Benefits: New, more durable overlay material that is not as susceptible to rutting and shoving as asphalt and can be placed in thin, flexible layers.

Products: Specifications, design criteria, and construction procedures for flexible cementitious overlays.

Implementation: This project will result in draft specifications, design criteria, and construction procedures for flexible cementitious overlays.

Problem Statement AM 1.2. High-Performance, Fiber-Reinforced Concrete Pavements

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 1. Performance-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $1M–$2M

In recent years, advancements have been made regarding the use of fiber reinforcement for improving concrete pavement performance. The first goal of this project will be to synthesize the information available about this topic. The researcher could then determine the potential of advanced fiber concepts aimed at extending the long-life pavement category. Attention should be given to both the benefits and drawbacks of using fiber reinforcement. The end product would include both procedural and analytical guidance for the optimum use of fibers. It is anticipated that this research will explore the field of fracture mechanics and will lead to a better understanding of the impacts that fibers can play on load transfer (as compared to dowels and tie-bars).

Tasks:

1. Identify different fiber types and previous use of fibers in concrete pavement.

2. Identify desirable properties for paving concrete with fibers to achieve long-life, high-performance pavements.

3. Identify, through lab testing or field tests, optimum fiber types and proportions for different paving applications (including varying climates).

4. Develop design recommendations, specifications, and construction procedures for incorporating fibers into paving concrete mixes.

5. Evaluate design recommendations and construction procedures in pilot projects.

Benefits: Fiber-reinforcement that will result in high-performance concrete pavement that is less susceptible to microcracking from concrete shrinkage than other pavements, resulting in a more durable, long-lasting pavement.

Products: Design recommendations, construction procedures, and specifications for fiber-reinforced concrete pavement.

Implementation: This project will result in design recommendations, construction procedures, and specifications for fiber-reinforced, high-performance concrete pavement.

Problem Statement AM 1.3. Pervious Concrete Pavement Program

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 1. Performance-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $500k–$1M

Pervious or porous concrete pavement has several notable advantages over conventional concrete pavement, primarily noise reduction and better drainage. Certain types of pervious pavement can pass three to five gallons of water per minute, which is far greater than most conceivable rain events and highly effective in reducing the risk of hydroplaning. Porous concrete also offers improved filtration and an enormous amount of surface area to catch oils and chemical pollutants, which can reduce skid and environmental damage. Some experts believe that the bacteria living in these spaces break down pollutants, preventing much of the runoff pollution that normally occurs with traditional pavements. Most of the pervious pavements constructed thus far, however, have been for parking lots, not highway pavements. This research would investigate the use of pervious concrete in highway pavements, examining the advantages and disadvantages, including the feasibility of large-scale pavement construction. The study should examine long-term maintenance and durability issues, such as permeability, abrasion resistance, and wetting/drying, as well as the effect of the bacteria. Stages of this research would include the development of mix design techniques as well as the field trial phase.

Tasks:

1. Identify previous applications of pervious concrete usage for pavements (including bases and subbases).

2. Identify required properties for application of pervious concrete to highway pavements.

3. Identify construction requirements for pervious concrete pavements, including pavement structure (subgrade, base, etc.).

4. Develop design recommendations, specifications, and construction procedures for pervious concrete for highway pavements.

5. Develop pilot projects for testing pervious concrete pavement for highway applications.

Benefits: Pervious concrete pavements that will drain water from the pavement surface without the need for a cross slope, improving the safety of the pavement surface; promotion of the breakdown of chemical pollutants due to the large surface area within the pavement surface.

Products: Design recommendations, construction procedures, and specifications for pervious concrete pavement for highway pavements.

Implementation: This project will result in design recommendations, construction procedures, and specifications for using pervious concrete for highway pavements.

Problem Statement AM 1.4. Carbon Dioxide Treated Materials

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 1. Performance-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $100k–$250k

The treatment of cementitious materials with gaseous carbon dioxide to achieve rapid strength development has been studied for many years. Recently, advances have been made in the treatment of cementitious materials that will facilitate the use of supercritical carbon dioxide in achieving a ten-fold reduction in permeability, while strength increases by several fold. While the precast concrete industry already uses this technology, further research is needed to apply the technology to pavements. In particular, research is needed to better understand the mechanisms of rapid strength development in concrete with supplementary cementitious materials. With further research, this process could likely lead to the development of new materials from novel waste streams and accelerate the development of new and improved concrete mixtures.

Tasks:

1. Identify previous applications of carbon dioxide treatment to concrete materials.

2. Identify beneficial properties for pavements using carbon dioxide-treated materials.

3. Identify procedures for incorporating carbon dioxide into materials for concrete pavements.

4. Conduct laboratory testing and/or pilot projects to evaluate carbon dioxide-treated materials for concrete pavements.

5. Develop recommendations for using carbon dioxide-treated materials for concrete pavements.

Benefits: Carbon dioxide treated materials that will increase strength and the rate of strength development, while significantly decreasing permeability, resulting in more durable pavements that can be opened to traffic faster.

Products: Recommendations for using carbon dioxide treated materials for concrete pavements.

Implementation: This project will result in recommendations for using carbon dioxide treated materials for concrete pavements.

Problem Statement AM 1.5. Reactive Powder Concretes as Ductile Materials

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 1. Performance-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $500k–$1M

With a technological breakthrough at the beginning of the 1990s, reactive powder concrete (RPC) offered compression strengths in excess of 200 MPa, flexural strengths of over 40 MPa, and ductility. Ductal and BSI, two products of the RPC family developed in France, are considered ultra-high-performance concretes. They are ductile materials capable of resisting substantial flexural loads and do not require passive reinforcement. This enables the overall thickness of structural elements to be reduced. The material is also extremely durable with very low permeability. Thus far, this material has predominantly been used in Europe for concrete structures, but future research should investigate its use in concrete pavements with or without fibers.

Tasks:

1. Identify RPC mixtures that could be used for concrete pavement, the properties of these mixes, and the advantages of these mixes (i.e., elimination of reinforcement, etc.).

2. Identify the properties required to use RPC in concrete pavement.

3. Conduct laboratory testing and/or field trials using RPC for concrete pavement construction.

4. Develop pavement design recommendations, specifications, and construction procedures for concrete pavements constructed using RPC.

Benefits: Ultra-high-performance concretes using RPC that are very high-strength concretes with ductility and very low permeability; the possibility of thinner pavement sections and a reduction or elimination of reinforcement, resulting in a more durable pavement that is cheaper to construct.

Products: Design and material recommendations and construction procedures for using RPC for ultra-high-performance concrete pavements.

Implementation: This project will result in design and material recommendations, specifications, and construction procedures for using RPC to achieve ultra-high-performance concrete pavements.

Problem Statement AM 1.6. Chemically Bonded Ceramic (Ceramicrete)

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 1. Performance-Enhancing

Approx. Phasing: N/A

Estimated Cost: $100k–$250k

Chemically bonded ceramic (Ceramicrete) is a type of concrete with very low permeability. Ceramicrete is formed when magnesium oxide powder and soluble phosphate powder (both available, low-cost materials) are mixed with water, creating a nonporous material with compressive strength higher than that of concrete. As described by the developer, Argonne National Laboratory, "Ceramicrete can be made with commercially available equipment that mixes the powder components into the binder. The wet material (binder, aggregates, and water mixture) can then be pumped, gunned, or sprayed, also with commercially available equipment." The feasibility (costs and benefits) of using Ceramicrete for concrete paving should be explored.

Tasks:

1. Identify Ceramicrete mixes and their properties (strength, permeability, workability, long-term durability) and cost.

2. Evaluate the feasibility of using Ceramicrete for concrete pavement construction, considering constructability, durability, and cost.

3. Develop recommendations for using Ceramicrete in concrete paving applications, including repairs, overlays, and new construction.

Benefits: Better corrosion resistance and strength characteristics for concrete pavements, resulting from Ceramicrete's very low permeability and higher compressive strength than normal-strength concrete.

Products: Recommendations for the use of Ceramicrete for concrete paving applications.

Implementation: This project will result in recommendations for the use of Ceramicrete for concrete paving applications, including repairs, overlays, and new construction.

Problem Statement AM 1.7. Localized High-Quality Concrete at the Joints

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 1. Performance-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $1M–$2M

Many concrete pavement failures occur because of joint damage. Improving the quality of the concrete at these potential weak areas would thus increase the overall pavement life. Therefore, a system should be developed to ensure that the concrete at the joints consists of a higher quality material than the concrete mid-slab. This process could involve the introduction of fibers, chemicals, or other additives at the joints.

Tasks:

1. Identify joint failure mechanisms in concrete pavements.

2. Identify possible materials—i.e. high-quality concrete—for improving the toughness and durability of joints.

3. Develop construction techniques for incorporating high-quality material into the paving process at the joints.

4. Conduct field trials/accelerated pavement testing of pavements constructed with high-quality materials at the joints.

5. Develop design recommendations and construction procedures for concrete pavements with high-quality materials at the joints.

Benefits: High-quality material at the joint regions in concrete pavements that may not be affordable for use in the rest of the slab, ensuring better joint toughness and durability and enhancing pavement life.

Products: Recommendations for using high-quality materials at the joints in concrete pavements.

Implementation: This project will result in design construction recommendations for using high-quality materials at the joints in concrete pavements.

Problem Statement AM 1.8. Alternative Reinforcement Material for Continuously Reinforced Concrete Pavements

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 1. Performance-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $500k–$1M

Steel reinforcement is a critical component of continuously reinforced concrete pavements. However, factors such as concrete permeability and water infiltration at cracks, the resultant corrosion of steel reinforcement, and the associated tendency of concrete to lose bond action with imbedded reinforcement reduce structural performance over time. Research is needed to develop economical, thermodynamically durable, metallic and nonmetallic corrosion-resistant reinforcements. Widespread use of these technologies, which have been researched for many years, will lead to additional refinements, such as the further development of fiber-reinforced plastic (FRP) bars with a useful form of pseudo-ductility that makes full use of their strength. Another advantage of alternate reinforcing materials for continuously reinforced concrete pavements (CRCP) is reduced placement costs. Lighter weight FRP will require less labor to place and may be better suited for slip-form paving trains that automatically place the reinforcement. The researchers should begin by looking at work that has previously been done in this area, including ongoing studies sponsored by the FHWA at West Virginia University.

Tasks:

1. Identify alternative metallic and nonmetallic reinforcing materials.

2. Evaluate the suitability of these materials for CRCP construction, considering properties such as strength, modulus of elasticity, bond strength, corrosion resistance, ductility, cost, and constructability.

3. Conduct laboratory testing and/or pilot projects to evaluate the viability of these materials for CRCP construction.

4. Develop recommendations for types and usage of alternative reinforcement, including design recommendations based on properties of each specific material.

Benefits: Alternative reinforcing materials that provide better corrosion resistance, bond strength, and modulus of elasticity; lighter materials that reduce labor costs during placement and dependence upon a volatile steel market.

Products: Recommendations for alternative reinforcing materials for CRCP.

Implementation: This project will result in recommendations for the design and use of alternative reinforcing materials for CRCP.

Subtrack AM 2. Construction-Enhancing Concrete Pavement Materials

The materials developed under this subtrack address specific constructability issues and provide creative alternatives to conventional concrete. The problem statements in this subtrack will develop special concrete materials for use in various concrete paving applications.

Problem Statement	Estimated Cost	Products	Benefits
AM 2.1. Application of Self-Consolidating Concrete for Concrete Paving	$500k–$1M	Recommendations for design and construction of pavements using SCC.	Better consolidation of concrete around dowels and reinforcement, reducing the need for vibration, resulting in a more durable pavement while reducing labor costs during construction.
AM 2.2. Applying Very High Strength Concrete to Pavement Operations	$1M–$2M	Mix design recommendations, construction procedures, and specifications for very high strength concrete pavements.	Concrete pavement with a very high tensile strength to permit longer sections of pavement to be constructed, reducing the number of joints, and helping to reduce cracking and improve long-term durability.
AM 2.3. Dry-Laid Concrete	$500k–$1M	Design and construction guidelines and recommendations for dry-laid concrete pavement.	Dry-laid concrete pavement that eliminates the need for mixing concrete on-site (batch-plants) and permits thinner, durable pavement slabs, greatly reducing construction and materials costs.
AM 2.4. Energetically Modified Cement	$100k–$250k	Recommendations for the use of EMC for concrete paving mixes.	EMC with faster strength development and better long-term strength of blended mixes, resulting in more durable pavements using blended mixes that can be opened to traffic sooner.
AM 2.5. Advanced Curing Materials	$250k–$500k	Recommendations for advanced curing materials and the requirements for these materials.	More effective curing materials for concrete paving operations, especially those constructed under short construction windows and in extreme environments; advanced curing materials that better ensure the necessary curing requirements, resulting in a more durable pavement.
AM 2.6. Cold Weather Concreting Advancements	$500k–$1M	Recommendations for cold-weather paving mixes and construction practices.	Cold-weather tolerant concrete paving mixes and construction techniques that will extend the pavement construction season in colder regions and reduce the labor required to protect pavements during cold-weather paving operations.
AM 2.7. Advancements in Internal Curing of Concrete	$250k–$500k	Mix design recommendations that will promote IC of concrete pavements.	IC that will help reduce autogenous shrinkage and self-desiccation and will ensure more complete hydration of cementitious materials, resulting in a less permeable, stronger, more durable pavement.

AM 2.8. Self-Curing Concrete	$250k–$500k	Recommendations on materials and techniques for constructing self-curing concrete pavements.	Self-curing concrete pavements that will reduce dependence on the contractor to apply adequate curing measures to new concrete pavement; more complete hydration of the cementitious materials, resulting in stronger, less permeable, and more durable concrete pavements.

Problem Statement AM 2.1. Application of Self-Consolidating Concrete for Concrete Paving

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 2. Construction-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $500k–$1M

Significant interest in recent years has arisen over the use of self-consolidating concrete (SCC) for various applications. The most common application is in complex structural work, where the presence of the reinforcing steel has made adequate consolidation using conventional means difficult. Because some concrete paving work faces similar challenges with consolidation (near dowels and reinforcements), using SCC for concrete paving has been suggested. As part of this effort, the researcher will evaluate innovative ways to incorporate SCC into PCC pavements that include full sections, overlays, inlays, and patching, for both fixed-form and slip-form operations. This work is anticipated to build on work already underway by the FHWA and other organizations.

Tasks:

1. Identify previous applications of SCC for pavements or slab-on-grade.

2. Identify desirable mix properties for using SCC in pavements.

3. Develop mix design recommendations for using SCC for pavements.

4. Develop best practice construction procedures for using SCC for new construction, overlays, inlays, and patching.

5. Conduct lab testing and/or pilot projects to test SCC for pavements, including an evaluation of consolidation around dowels and reinforcements.

Benefits: Better consolidation of concrete around dowels and reinforcement, reducing the need for vibration, resulting in a more durable pavement while reducing labor costs during construction.

Products: Recommendations for design and construction of pavements using SCC.

Implementation: This project will result in design recommendations and best practice construction procedures for using SCC for pavements.

Problem Statement AM 2.2. Applying Very High Strength Concrete to Pavement Operations

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 2. Construction-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $1M–$2M

High-strength concrete is currently being used in rapid-cure patches. However, the high cement content causes high temperatures that can result in thermal contraction problems. At present, early opening is the only advantage to using higher strength concrete in pavements. Also, such concrete is expensive, and if higher strength pavements are to be competitive, ways to minimize the amount of the expensive concrete must be found. The French have developed a two-layer extruded slip-form operation that encapsulates normal concrete within a protective high-strength concrete. Other more economical options might also be considered, such as slabs cast with internal voids, or beam and slab configurations, although data is needed on deflection, water movement, friction, curling, and warping of unusual slab configurations. Jointing technology would also be needed. A vigorous research study would be needed to make the use of 69 MPa (10,000 psi) concrete more efficient for structural pavements.

Just as continuously welded rails are used, it should be possible to construct a continuous ribbon of concrete that would withstand a temperature range of 55 degrees C (100 degrees F). A tensile strength of about 17 MPa (2500 psi) would be needed, which might be possible with a compressive strength of about 172 MPa (25,000 psi) (plus a factor of safety). This could be accomplished with polymer impregnation if a field process could be developed. For comparison, a laboratory strength of about 731 MPa (106,000 psi) has been attained with portland cement. Special concretes are currently being used in the 172 MPa (25,000 psi) range, based on a reactive powder process. The strength must be attained about 18 hours before the concrete begins to cool and contract. Of course, such continuous ribbons of ultra-high-strength concretes will experience about 50 mm (2 in.) of movement at the ends, making special anchors or joints necessary.

Tasks:

1. Identify high-strength mixes and the properties (i.e., strength, shrinkage, and workability) of these mixes.

2. Determine the suitability of these mixes for paving applications based upon these properties.

3. Modify existing mixes or develop new mixes to meet paving requirements.

4. Identify construction requirements (i.e., special curing procedures) for using high-strength mixes for pavements.

5. Identify alternative paving techniques (e.g., voided or hollow slabs) to reduce the quantity and cost of using high-strength mixes.

6. Conduct lab testing and/or field trials of high-strength pavements.

7. Develop mix design recommendations, construction procedures, and specifications for high-strength concrete pavements.

Benefits: Concrete pavement with a very high tensile strength to permit longer sections of pavement to be constructed, reducing the number of joints, and helping to reduce cracking and improve long-term durability.

Products: Mix design recommendations, construction procedures, and specifications for very high strength concrete pavements.

Implementation: This project will result in mix design recommendations, construction procedures, and specifications for high-strength concrete pavements.

Problem Statement AM 2.3. Dry-Laid Concrete

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 2. Construction-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $500k–$1M

New formulations and procedures have been developed that enable concrete to be placed as a cementitious dry mix that is then watered from above to produce a strong, thin slab or pavement. The need for onsite mixing is thus eliminated. In the field, the strength of dry-laid slabs only 10 to 50 mm thick saves raw materials and excavation costs and may make resurfacing old concrete a practical possibility. Dry-lay materials are also easier to work with than conventional moist or semidry concrete screeds and should result in a stronger and more durable end product.

Preliminary tests indicate that strong concrete substantially free of shrinkage cracking can be produced by dry-lay methods using premixed materials in which the maximum particle size is limited, typically to 5-mm diameter. The absence of large particles means that thinner slabs of concrete down to 10 mm can be laid. Although the mixture has a higher cement and fines content than conventional concrete, the dry-lay process reduces the problem of self-induced cracking due to drying shrinkage that is generally encountered with cement-rich mortars laid as a wet mix. Although the product was originally conceived as an easy-to-use, do-it-yourself surfacing product, there appears to be a major opportunity to apply it to concrete paving. Innovative aspects of dry-lay techniques include the following:

- Need for mixing on site eliminated; more easily placed than wet or semi-dry mixes; factory-mixed precision carried through to final placement; problems of premature setting avoided
- The strength of concrete and the thinness of mortars or screeds combined; readily compatible with the delivery of dry mixes in silos and mechanized placement
- Early resistance to traffic
- Convenient material for patching repairs and extensive resurfacing of old concrete as well as new pavements
- Attractive surface finishes can be incorporated; economical to produce.

Tasks:

1. Identify dry-laid concrete materials, techniques, and previous applications.

2. Identify required properties for dry-laid concrete for PCC pavements and benefits of using dry-laid concrete over conventional wet construction.

3. Identify materials and techniques for dry-laid concrete that will meet the requirements for PCC pavements.

4. Perform laboratory testing and/or field trials to evaluate the viability of dry-laid concrete for pavements.

5. Develop design recommendations and construction procedures for using dry-laid concrete for overlays, repairs, and new construction.

Benefits: Dry-laid concrete pavement that eliminates the need for mixing concrete on-site (batch-plants) and permits thinner, durable pavement slabs, greatly reducing construction and materials costs.

Products: Design and construction guidelines and recommendations for dry-laid concrete pavement.

Implementation: This project will result in recommendations for using dry-laid concrete for PCC pavements, including design guidelines and construction procedures.

Problem Statement AM 2.4. Energetically Modified Cement

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 2. Construction-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $100k–$250k

One important constraint of using cement blended with various pozzolanic or cementitious substances (fly ash, blast furnace slag, etc.) is the early strength development requirements included in current standards. Blended cements typically take longer to develop their strength and often do not meet standards without additives. Energetically modified cement (ECM) is a patented technology that has overcome this obstacle. By intensively grinding and activating the cement together with the pozzolan, the surfaces of the particles are activated. The investigators of this technology believe that the activation creates a network in the cement particles of sub-microcracks, microdefects, and dislocations that allows the water to penetrate deeper into the cement particles, which in turn uses a higher percentage of the potential binding capacity of the cement. This process also allows inert fillers, such as fine quartz sand, to be activated. The EMC technology is based solely on grinding; no additives of any kind are used. Evaluations and tests of concretes and mortars made with EMC have shown EMC to perform significantly better than portland pozzolan blended cements containing 20–40 percent fly ash. EMC with fly ash, by comparison, allows for a 10 percent reduction in water-cement ratio, translating to higher long-term strength. EMC also showed slightly improved sulfate resistance, and the workability of EMC was better than cement.

Tasks:

1. Identify the energetically modified cements (EMC) and cement-pozzolan blends and their specific properties (strength, permeability, workability, long-term performance, etc.).

2. Identify the benefits of using EMC for concrete pavement mixes and evaluate the suitability of its properties for concrete pavement construction, considering cost and the variable climates pavements are constructed in .

3. Develop recommendations for using EMC for concrete paving mixes with consideration for proprietary specifications.

Benefits: EMC with faster strength development and better long-term strength of blended mixes, resulting in more durable pavements using blended mixes that can be opened to traffic sooner.

Products: Recommendations for the use of EMC for concrete paving mixes.

Implementation: This project will result in recommendations for the use of EMC for concrete paving mixes.

Problem Statement AM 2.5. Advanced Curing Materials

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 2. Construction-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $250k–$500k

Curing methods used for concrete paving have not changed significantly in the last 30 years. Liquid curing compound remains the most commonly used form of protection. However, the demands being placed on concrete paving are evolving. Rapid reconstruction and extreme weather events have challenged traditional curing methods and resulted in a demand for better solutions. This project will investigate new and advanced curing materials for use in these extreme circumstances. Effectiveness, cost, and proprietary issues should be considered. Ideally, the project will result in a performance or end-result standard for advanced curing materials that would allow for adequate competition and provide the user with the desired properties. To further this goal, a functional specification could be developed that establishes critical moisture and temperature conditions required to achieve varying degrees of quality. The ability of the cure to meet these functional thresholds would determine its quality.

Tasks:

1. Identify advanced curing materials that could be used for concrete pavement construction, soliciting ideas for new materials if the number of existing materials is limited.

2. Evaluate the effectiveness of these materials, with consideration given to special circumstances such as rapid reconstruction and extreme climatic conditions.

3. Develop recommendations for required effectiveness of curing materials, considering critical moisture and temperature conditions under which the materials must provide adequate curing conditions.

4. Develop recommendations for advanced curing materials, ensuring that the requirements are such that a sole proprietary product is not the only available material.

Benefits: More effective curing materials for concrete paving operations, especially those constructed under short construction windows and in extreme environments; advanced curing materials that better ensure the necessary curing requirements, resulting in a more durable pavement.

Products: Recommendations for advanced curing materials and the requirements for these materials.

Implementation: This project will result in recommendations for different types of advanced curing materials and requirements for the effectiveness of these materials.

Problem Statement AM 2.6. Cold Weather Concreting Advancements

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 2. Construction-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $500k–$1M

U.S. Army Corps of Engineers researchers are experimenting with concrete admixtures that allow for subzero pours as low as -15 degrees C (5 degrees F) in the open air . Underwritten by ten state transportation departments, the three-year, 750,000-dollar program is paving the way for reduced labor in winter months and a longer construction season. The team is working with combinations of off-the-shelf products in order to lower the freezing temperature of concrete. These substances, which are commonly available to contractors, include concrete accelerators, corrosion inhibitors, and plasticizers already governed by their own set of standards. One recent study involved a 32-m-long (104-ft-long) bridge curb in Lebanon, New Hampshire. The result of using the lab's experimental concrete was a savings of 132 labor hours needed to build an enclosure and 50 dollars in liquid propane. The total cost was 700 dollars rather than 750 dollars plus labor for traditional methods. The next step is to develop a recipe guide for admixture chemicals. Beyond this, research is still needed to demonstrate the benefits of this technology for concrete pavements.

Tasks:

1. Identify materials and concrete mixtures that permit concrete placement in subzero conditions without special measures to protect the concrete.

2. Evaluate the properties of these materials and the viability of their use in concrete pavements.

3. Conduct laboratory or field trials of cold-weather concretes for paving projects.

4. Evaluate the cost vs. benefits of cold-weather concretes, giving consideration to extending the construction season and reducing cold-weather construction labor.

5. Develop recommendations for cold-weather pavement mixes and construction and curing procedures.

Benefits: Cold-weather tolerant concrete paving mixes and construction techniques that will extend the pavement construction season in colder regions and reduce the labor required to protect pavements during cold-weather paving operations.

Products: Recommendations for cold-weather paving mixes and construction practices.

Implementation: This project will result in recommendations for cold-weather concrete paving mixes and construction practices.

Problem Statement AM 2.7. Advancements in Internal Curing of Concrete

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 2. Construction-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $250k–$500k

In the last few years, internal curing (IC) has evolved into a science. With the advent of lower water-concrete ratio mixtures and high-performance concrete, the need for a system to eliminate autogenous shrinkage and self-desiccation has developed, and the use of lightweight fines for the IC of concrete is increasingly being recognized. George Hoff's paper, "Internal Curing of Concrete Using Lightweight Aggregate" (CANMET/ACI International Conference in Thessaloniki, Greece June 1–7, 2003) includes a state-of-the-art of practice in this area. In this research, the use of IC for concrete pavement will be explored. The costs and benefits of this technology should be weighed and a recommendation made for proceeding with field trials and other implementation projects.

Tasks:

1. Identify materials and techniques to promote IC of concrete.

2. Evaluate the properties of concrete made with these materials, including workability, durability, strength, and permeability, and the suitability of these materials for concrete pavements.

3. Conduct laboratory testing to evaluate the effectiveness of IC for concrete paving applications.

4. Develop recommendations for materials and concrete mixes that will provide IC for concrete pavement applications.

Benefits: IC that will help reduce autogenous shrinkage and self-desiccation and will ensure more complete hydration of cementitious materials, resulting in a less permeable, stronger, more durable pavement.

Products: Mix design recommendations that will promote IC of concrete pavements.

Implementation: This project will result in material and mix-design recommendations that will promote IC of concrete pavements.

Problem Statement AM 2.8. Self-Curing Concrete

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 2. Construction-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $250k–$500k

Most paving mixtures contain adequate mixing water to hydrate the cement if the moisture is not allowed to evaporate. It should be possible to develop an oil, polymer, or other compound that would rise to the finished concrete surface and effectively seal the surface against evaporation. R.K. Dhir recently published some test results on self-curing mixtures. This research will further explore the potential of self-curing concrete.

Tasks:

1. Identify materials or techniques for developing self-curing concrete.

2. Evaluate the suitability of these materials for concrete pavement applications, considering workability, strength, permeability, and durability.

3. Conduct laboratory testing or field trials to evaluate the effectiveness of self-curing concrete for paving applications.

4. Develop recommendations on materials and techniques for self-curing concrete pavements.

Benefits: Self-curing concrete pavements that will reduce dependence on the contractor to apply adequate curing measures to new concrete pavement; more complete hydration of the cementitious materials, resulting in stronger, less permeable, and more durable concrete pavements.

Products: Recommendations on materials and techniques for constructing self-curing concrete pavements.

Implementation: This project will result in recommendations on materials and techniques for constructing self-curing concrete pavements.

Subtrack AM 3. Environment-Enhancing Concrete Pavement Materials

The problem statements in this subtrack will address environmental concerns in concrete pavement materials, construction, and performance. The materials developed in this research can be used to improve air quality and will enhance recycled concrete pavement materials.

Problem Statement	Estimated Cost	Products	Benefits
AM 3.1. Cement Containing Titanium Dioxide	$100k–$250k	Recommendations for the use of cement containing titanium dioxide in concrete paving mixes.	Concrete pavements containing titanium dioxide that can potentially remove certain volatile organic compounds from the air, helping to reduce air pollution in urban areas.
AM 3.2. Sulfur Concrete	$100k–$250k	Recommendations for the use of sulfur concrete in paving applications.	Sulfur concrete that consists of 100 percent recycled material, made from byproducts of electricity production and petroleum refinement; a dense, acid resistant material that may have applications for concrete paving.
AM 3.3. Increased Percentages of Reclaimed Asphalt Pavement as an Aggregate for Concrete Paving Mixtures	$1M–$2M	Recommendations for using RAP as an aggregate for concrete paving mixes.	RAP in concrete paving mixes, reducing the amount of RAP that must be disposed of, as well as reducing the demand for virgin aggregate for concrete pavements.
AM 3.4. Mix Design Considerations with Recycled Concrete Aggregate	$1M–$2M	Recommendations for using recycled concrete as aggregate in new pavement construction.	Recycled concrete for aggregate in new concrete pavements, reducing the amount of reclaimed concrete pavement that must be disposed of, as well as the demand for virgin aggregate in concrete pavements.
AM 3.5. Acceptance Criteria for using Recycled Aggregate	$500k–$1M	Recommendations for acceptance criteria and test procedures for recycled aggregate and concrete made with recycled aggregate.	Established acceptance criteria and test procedures for recycled aggregate in new concrete pavements to promote the use of recycled aggregates, thereby reducing the demand for virgin aggregate for new construction.
AM 3.6. Waste Materials in Concrete Mixes	$1M-2M	Recommendations (proportions and limits) for the use of waste materials in concrete paving mixes.	Use of waste materials in concrete mixes, reducing the amount of waste materials and the demand for cement (which must be produced), while producing a better concrete mix.
AM 3.7. Ecocement for Concrete Mixes	$100k-250k	Recommendations for the production and use of Ecocement in the United States.	Ecocement that is produced during the incineration of solid waste and sewage sludge, reducing the amount of waste, while reducing the amount of cement required for concrete paving mixes, resulting in a faster setting concrete mix.

AM 3.8. Polymer Concrete Made from Recycled Plastic Bottles	$100k-250k	Recommendations for using polymer concrete for paving applications.	Polymer concrete that results in a more durable pavement or pavement overlay, making use of recycled plastic bottles and reducing the demand on landfills.

Problem Statement AM 3.1. Cement Containing Titanium Dioxide

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 3. Environment-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $100k–$250k

To help reduce air pollution and prevent the discoloration of urban concrete surfaces, several cement companies, including Italcementi and Taiheiyo, have marketed cement containing a photocatalyst (titanium dioxide) , which removes polluting volatile organic compounds (VOCs) from the atmosphere and converts them to carbon dioxide (CO_2). If put into widespread use, such cement could potentially improve urban air quality (e.g., reduce smog), since the amount of CO_2 produced would be much smaller than the amount of CO_2 from combustion sources. The use of cementitious materials containing photocatalysts is thus an innovative and profitable way to eliminate pollutants, particularly in urban areas. Concrete pavement would be an ideal application for such a product, as the pavement could decrease the smog that the vehicles traveling over the pavement produce.

Tasks:

1. Identify concrete mixes containing titanium dioxide that have been shown to remove VOC air pollutants.

2. Identify the properties of these mixes and evaluate their suitability for concrete pavement applications.

3. Conduct laboratory testing or field trials to evaluate the effectiveness of these mixes for reducing pollution.

4. Develop recommendations for using titanium dioxide concrete mixes for concrete paving mixes.

Benefits: Concrete pavements containing titanium dioxide that can potentially remove certain volatile organic compounds from the air, helping to reduce air pollution in urban areas.

Products: Recommendations for the use of cement containing titanium dioxide in concrete paving mixes.

Implementation: This project will result in recommendations for the use of cement containing titanium dioxide in concrete paving mixes.

Problem Statement AM 3.2. Sulfur Concrete

Track:	Track 12. Advanced Concrete Pavement Materials (AM)
Subtrack:	Subtrack AM 3. Environment-Enhancing Concrete Pavement Materials
Approx. Phasing:	N/A
Estimated Cost:	$100k–$250k

Sulfur concrete is made from sulfur collected from the petroleum refining process and coal ash from coal burning thermal power stations. The process applies vibration and pressure to a mixture of heated sulfur and coal ash. The resulting concrete is 100 percent recycled. Hardened sulfur concrete is dense and acid resistant enough to be used where portland cement concrete cannot be used. Although most concrete pavements will not need such a high level of resistance, a feasibility study may be warranted to determine whether sulfur concrete could be used for concrete paving.

Tasks:

1. Identify sulfur concrete mixes and their properties, including strength, permeability, and durability.

2. Evaluate the feasibility of sulfur concrete for concrete pavement, specifically constructability, durability, cost, and specific applications where it may be beneficial.

3. Develop recommendations for the use of sulfur concrete in concrete paving applications.

Benefits: Sulfur concrete that consists of 100 percent recycled material, made from byproducts of electricity production and petroleum refinement; a dense, acid resistant material that may have applications for concrete paving.

Products: Recommendations for the use of sulfur concrete in paving applications.

Implementation: This project will result in recommendations for the use of sulfur concrete for concrete paving applications.

Problem Statement AM 3.3. Increased Percentages of Reclaimed Asphalt Pavement as an Aggregate for Concrete Paving Mixtures

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 3. Environment-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $1M–$2M

One of the main problems with rehabilitating or reconstructing existing asphalt pavement is the question of what to do with the wasted reclaimed asphalt pavement. Much of the time it is recycled back into a new asphalt pavement or used as embankment material. Though it has been recycled back into concrete on occasion (Austria does it regularly), its use and performance has not been widespread or documented in the United States. This research intends to determine whether reclaimed asphalt pavement (RAP) can be used as an aggregate in concrete pavements. The specific objectives will help determine the expected performance and potential detrimental effects of using RAP for aggregate in concrete.

Tasks:

1. Identify previous applications of RAP used as an aggregate in concrete paving mixtures.

2. Identify the properties of RAP aggregate concrete mixes (strength, durability, workability, etc.) and their suitability for concrete pavement construction.

3. Conduct laboratory testing and/or field trials of RAP aggregate concrete mixes.

4. Develop recommendations for using RAP in concrete mixes, with specific guidance as to acceptable RAP materials that can be used.

Benefits: RAP in concrete paving mixes, reducing the amount of RAP that must be disposed of, as well as reducing the demand for virgin aggregate for concrete pavements.

Products: Recommendations for using RAP as an aggregate for concrete paving mixes.

Implementation: This project will result in recommendations, including mix design recommendations and limits for RAP properties, for using RAP as an aggregate in concrete paving mixes.

Problem Statement AM 3.4. Mix Design Considerations with Recycled Concrete Aggregate

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 3. Environment-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $1M–$2M

To determine innovative ways to use recycled concrete in PCC pavements, this research will investigate the boundaries of using recycled materials in bases and two-lift construction; investigate its use in shorter performance life pavements, such as eight-year pavement; and investigate using portions of the product (i.e., fine or coarse fractions). The FHWA's program for recycled concrete should be reviewed before executing this effort.

Tasks:

1. Identify previous studies of recycled concrete for concrete aggregate and gaps in the knowledge that still remain.

2. Identify the properties of concrete made with recycled concrete aggregate (strength, permeability, workability, durability) and the limits of recycled concrete in new mixes.

3. Identify applications for concrete made with recycled concrete aggregate, such as two-lift construction and shorter life pavement.

4. Develop recommendations for using recycled concrete as aggregate in new concrete paving mixes, including mix design and pavement design recommendations and construction procedures.

Benefits: Recycled concrete for aggregate in new concrete pavements, reducing the amount of reclaimed concrete pavement that must be disposed of, as well as the demand for virgin aggregate in concrete pavements.

Projects: Recommendations for using recycled concrete as aggregate in new pavement construction.

Implementation: This project will result in recommendations for using recycled concrete as aggregate in new paving mixes, including limits for usage.

Problem Statement AM 3.5. Acceptance Criteria for Using Recycled Aggregate

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 3. Environment-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $500k–$1M

The use of recycled aggregate in concrete pavement is of great interest for reducing waste and reusing materials available at the job site. Using recycled aggregate will also reduce the amount of aggregate hauled to the job site. Research is needed to determine the applicability of standard tests and acceptance criteria for using recycled concrete as aggregate and PCC comprised of recycled concrete as aggregate.

Tasks:

1. Identify typical recycled aggregate materials and mix designs for concrete made with recycled aggregate.

2. Conduct laboratory testing using standard acceptance test procedures on aggregates and concrete mixes made with recycled aggregate.

3. Evaluate the suitability of these test procedures for recycled aggregates and concrete made with recycled aggregates.

4. Modify existing test methods or develop new test methods for acceptance testing of recycled aggregate and concrete made with recycled aggregate.

5. Develop recommendations for acceptance criteria and test procedures for recycled aggregate and concrete made with recycled aggregate.

Benefits: Established acceptance criteria and test procedures for recycled aggregate in new concrete pavements to promote the use of recycled aggregates, thereby reducing the demand for virgin aggregate for new construction.

Products: Recommendations for acceptance criteria and test procedures for recycled aggregate and concrete made with recycled aggregate.

Implementation: This project will result in recommendations for acceptance criteria and acceptance test procedures for recycled aggregate and concrete made with recycled aggregate.

Problem Statement AM 3.6. Waste Materials in Concrete Mixes

Track:	Track 12. Advanced Concrete Pavement Materials (AM)
Subtrack:	Subtrack AM 3. Environment-Enhancing Concrete Pavement Materials
Approx. Phasing:	N/A
Estimated Cost:	$1M–$2M

Fly ash, silica fume, and blast furnace slag are three common waste products that can be used to replace or supplement cement in concrete mixtures to produce more durable, workable, higher strength concrete. However, other waste materials, such as rice husk ash, palm oil fuel ash, and other agricultural wastes, are also proving to be effective materials for use in concrete. Sludge from paper mills can be heated to form metakaolin, which can be used as an additive for concrete, producing a very impermeable product. Additionally, recent studies show the benefits of using rubber particles from used tires to replace fine aggregate in portland cement based concrete used in roads.

Tasks:

1. Identify alternative waste materials that have been tested in concrete mixes and the benefits of these materials.

2. Establish optimal mix-design methods (or material optimization) for the waste materials.

3. Conduct laboratory testing to identify the properties of concrete mixes containing these materials, including strength, workability, permeability, and durability.

4. Develop recommendations for using these waste materials in concrete paving mixes, including proportions and limits of their use.

Benefits: Use of waste materials in concrete mixes, reducing the amount of waste materials and the demand for cement (which must be produced), while producing a better concrete mix.

Products: Recommendations (proportions and limits) for the use of waste materials in concrete paving mixes.

Implementation: This project will result in recommendations for the used of waste materials in concrete paving mixes, including proportions and limits.

Problem Statement AM 3.7. Ecocement for Concrete Mixes

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 3. Environment-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $100k–$250k

Ecocement replaces half of the traditional cement raw materials with ash generated by the incineration of municipal solid waste and sewage sludge. It has been recognized as "Type A Energy Efficient Cement" by the Japanese Institute of Civil Construction, Ministry of Construction, with the following characteristics:

- Rapid hardening, similar to high-early strength cement.
- Short initial setting time (approximately 20 to 40 minutes).
- Handling time that can be adjusted to suit particular applications by adding retarding admixtures.

During the Ecocement process, chinaware fragments in the incineration ash are used and metal wastes are extracted and recycled. Research is needed to determine the viability of producing and using this material domestically in concrete pavements.

Tasks:

1. Identify the Ecocement material and its properties.

2. Identify the process for manufacturing Ecocement.

3. Determine the viability of producing Ecocement in the United States and the cost vs. benefits of producing it.

4. Develop recommendations for producing and using Ecocement in concrete paving applications.

Benefits: Ecocement that is produced during the incineration of solid waste and sewage sludge, reducing the amount of waste, while reducing the amount of cement required for concrete paving mixes, resulting in a faster setting concrete mix.

Products: Recommendations for the production and use of Ecocement in the United States.

Implementation: This project will result in recommendations for producing and using Ecocement for concrete paving applications in the United States.

Problem Statement AM 3.8. Polymer Concrete Made from Recycled Plastic Bottles

Track: Track 12. Advanced Concrete Pavement Materials (AM)

Subtrack: Subtrack AM 3. Environment-Enhancing Concrete Pavement Materials

Approx. Phasing: N/A

Estimated Cost: $100k–$250k

Polymer concrete consists of organic polymers, typically unsaturated polyesters that bind inorganic aggregates, that essentially replace the hydraulic binders in cement with organic polymers. Polymer concrete can be used alone or as an overlay or coating on ordinary portland cement concrete to increase its durability and lifetime dramatically (see above). Recently, investigators have studied the use of resin obtained from recycled polyethylene terephthalate (PET) bottles (water and carbonated beverage containers). Recycled PET resin-based polymer concrete is stronger and cheaper than conventional polymer concrete. Recycling PET into polymer concrete also aids in waste disposal. Research is needed to determine the viability of this material for use in concrete pavements.

Tasks:

1. Identify polymer concretes made from recycled plastic and their properties—namely, strength, permeability, workability, durability, and cost.

2. Evaluate the viability and benefits of polymer concrete for concrete paving applications.

3. Develop recommendations for using polymer concrete for concrete paving applications, such as repairs, overlays, and new construction.

Benefits: Polymer concrete that results in a more durable pavement or pavement overlay, making use of recycled plastic bottles and reducing the demand on landfills.

Products: Recommendations for using polymer concrete for paving applications.

Implementation: This project will result in recommendations for using polymer concrete for concrete paving applications.