USDOT-SLAG-26-15
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United States Department of Transportation
Research Initiative on the Use of Steel Slag in Concrete and Cement

Office of the Assistant Secretary for Science and Technology (OST-R)

Research Plan

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Steel Slag Initiative 2026-2030 Research Plan

Overview of Research Areas and Timeline

This Research Plan has been developed after a robust evaluation of existing information and communication with industrial partners to advance use of steel slag as a value-added material in cementitious systems and broader transportation infrastructure applications. The Research Plan includes six interconnected research areas:

(1) Industry and market assessment

(2) Material characterization and processing

(3) Performance in concrete and cement systems

(4) Alternative material end uses

(5) Design and engineering integration

(6) Policy, implementation, and decision support.

Together, these areas establish a comprehensive framework that spans the full innovation pipeline ranging from understanding slag availability and properties to enabling large-scale adoption in construction and infrastructure systems.

The research strategy follows a phased progression to build knowledge, reduce uncertainty, and support implementation. Early efforts emphasize understanding the variability, supply chain dynamics, and processing requirements of steel slag. This foundation supports detailed evaluation of its mechanical, chemical, and durability performance in cementitious systems. As the program advances, focus shifts to engineering integration, development of specifications, and exploration of alternative applications. The final phase emphasizes implementation (pilot-scale), economic feasibility, and policy alignment to ensure scalability and industry adoption. A timeline for research progression is described below.

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Years 1–2 (August 2026 – July 2028): Foundational Assessment and Material Evaluation

The first phase focuses on establishing a robust understanding of steel slag sources, variability, and processing pathways. Activities include industry and market assessment to evaluate availability, logistics, and supply chain readiness. Concurrently, detailed material characterization will be conducted to assess chemical composition, mineralogy, volumetric stability, and physical properties. Processing strategies (e.g., aging, grinding, stabilization) will be explored to enhance material consistency and suitability for use in cementitious systems.

Year 3 (August 2028 – July 2029): Performance Validation and Application Development

The third year emphasizes expanded validation of steel slag in concrete and cement systems under a range of environmental and loading conditions. Research will focus on durability performance (e.g., expansion, carbonation, freeze-thaw resistance) and optimization of mixture designs. In parallel, alternative end uses, such as aggregates, soil stabilization, or other construction applications, will be explored.

Year 4 (August 2029 – July 2030): Integration, Implementation, and Decision Support

The final phase focuses on integrating steel slag into engineering practice and enabling its large-scale deployment. Activities include field demonstrations, validation of design methodologies, and incorporation into engineering specifications and standards. Life-cycle assessment and techno-economic analysis will quantify environmental and cost benefits relative to conventional materials. In addition, decision-support tools and policy-relevant insights will be developed to guide stakeholders, including industry, agencies, and designers, in adopting steel slag across a range of infrastructure applications.

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Research Area 1: Industry and Market Assessment

Focus: Establish a clear, data-driven understanding of the U.S. steel slag industry, including how materials are produced, processed, distributed, and perceived, in order to address key barriers to adoption.

Outcome: Develop foundational knowledge needed to align research with real-world conditions and support future specification, policy, and market development.

Topics of Interest:

Operations, Logistics, and Processing Assessment - Document current practices across steel slag production and processing facilities, including:

- Slag generation (EAF, BOF, ladle) and processing methods
- Stockpiling, aging, and handling practices
- Transportation logistics and regional supply chains
- Quality control and material tracking practices

Industry Perception and Barriers Assessment - Engage stakeholders across DOTs, industry, and academia to:

- Identify technical, economic, and regulatory barriers
- Understand acceptance requirements and risk concerns
- Evaluate current and potential applications

Terminology and Classification Standardization - Develop a consistent framework to:

- Define steel slag types and processing conditions
- Address inconsistencies across ASTM, AASHTO, and industry usage
- Support development of clear and adoptable specifications and policies

Potential Projects:

1. Operations, Logistics, and Market Assessment of Steel Slag Facilities
2. Survey of Industry Views on Steel Slag Use, Barriers, and Implementation
3. Assessment of Steel Slag as Feedstock for Cement or Clinker Production

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Research Area 2: Material Characterization and Processing

Focus: Develop a fundamental understanding of how steel slag production, processing, and activation influence material structure, reactivity, and engineering performance.

Outcome: Establish the processing–structure–property relationships needed to guide material optimization, enable performance predictions, and support specification development.

Topics of Interest:

Evaluation of Activation Methods - Investigate the effects of different activation approaches on steel slag behavior, including:

- Carbonation (including mineralization and CO_2 uptake potential)
- Thermal treatment (e.g., cooling rate, reheating, phase modification)
- Combined or hybrid activation approaches

Variability and Production Practices - Quantify the variability in material properties arising from:

- Steelmaking processes (EAF, BOF, ladle slag)
- Cooling methods (air cooling, quenching, water addition practices)
- Stockpiling, aging, and processing conditions

Processing Timeline and Material Evolution - Establish a framework to define:

- Key stages from slag generation to end use
- The concept of "time zero" and how material properties evolve over time
- Points in the supply chain where processing or activation can be applied

Potential Projects:

1. Effect of Activation Methods on the Structure–Reactivity Relationships in Steel Slag
2. Survey of Steel Slag Production Processes and Layouts
3. Assessment of Reactivity Testing for Steel Slags
4. Long-Term Volume Stability of Steel Slag in Concrete
5. Assessment of Transport in Activated Steel Slag using Neutron Radiography
6. Effect of Activation Methods on the Structure-Reactivity Relationships in Steel Slag: Carbonation
7. Effect of Activation Methods on the Structure-Reactivity Relationships in Steel Slag: Bio-Carbonation
8. Assessment Variability of Steel Slag and Evaluating their Performance in Concrete Mixtures
9. Assessing the Suitability and Accuracy of Volumetric Expansion Tests to Set Expansion and Compositional Limits in Steel Slag Concretes
10. Assessment of Reactivity Testing for Steel Slags

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Research Area 3: Performance in Concrete and Cement

Focus: Evaluate the engineering performance of steel slag in cement and concrete for practical applications and address key technical risks that currently limit adoption, including durability, constructability, and long-term stability.

Outcome: Generate reliable, application-relevant performance data to support material acceptance, specification development, and confidence among end users.

Topics of Interest:

Durability, Constructability, and Long-Term Behavior - Assess the performance of steel slag systems under realistic service conditions, including:

- Durability metrics such as freeze-thaw resistance, corrosion potential, and salt scaling
- Volumetric stability and expansion behavior over time
- Constructability factors including mixing, placement, finishing, bleed water, and curing requirements

Case Studies and Field Validation - Evaluate both existing and new implementations to bridge the gap between laboratory testing and real-world performance:

- Detailed investigation of existing infrastructure (e.g., long-term concrete slab performance)
- Field trials to assess constructability and early-age performance
- Integration of companion laboratory testing on field samples to provide controlled performance data

Potential Projects:

1. Study of Durability of Activated Steel Slag Systems in Concrete
2. Companion Laboratory Testing for Field Trials
3. Durability Performance of Ground and/or Granulated Steel Slags: Alkali-Silica Reaction
4. Durability Performance of Activated Steel Slags: Alkali-Silica Reaction
5. Comparative Analysis of Permeability and Resistivity Relationships in Steel Slag Concrete
6. Durability Performance of Activated Steel Slags: Delayed Ettringite Formation
7. Assessment of Rheology and Workability of Mortar and Concrete with Steel Slags
8. Implementation Project

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Research Area 4: Alternative Material End Uses

Focus: Evaluate alternative end uses for steel slag, prioritizing direct geotechnical applications with minimal processing. This involves characterizing baseline engineering performance, contaminant sequestration, and lifecycle durability under repeated loading. Additionally, it establishes utilization pathways for highly variable or off-spec slags not usable in cement or concrete applications.

Outcome: Advance the large-scale deployment of steel slag as a value-added resource across the broader transportation infrastructure sector by establishing validated performance baselines, clear material suitability criteria, and non-cementitious acceptance pathways for lower-specification or highly variable slag materials.

Topics of Interest:

Low-Processing Geotechnical Applications and Off-Specification Pathways

- Document and evaluate the engineering performance of raw, highly variable, or off-specification steel slags for use as direct aggregate replacements or road base.
- Develop clear material suitability criteria and engineering screening frameworks to safely match lower-grade or variable slag batches.

Engineering Performance, Durability, and Environmental Safety

- Characterize the mechanical properties, baseline performance, and long-term structural degradation of steel slag improved geomaterials under repeated lifecycle loading.
- Assess the chemical stabilization and leaching mechanisms governing the long-term immobilization of contaminants within steel slag treated soils and matrices.

Field Deployment, Advanced Simulation, and Specialized Uses

- Bridge the gap between laboratory screening and full-scale field implementations using structural-scale centrifuge testing and predictive numerical modeling.
- Investigate the design, rheology, and durability parameters required to successfully integrate steel slag into additive manufacturing applications.

Potential Projects:

1. Evaluating contaminant immobilization in steel slag treated geomaterials
2. Evaluation of engineering performance of steel slag improved geomaterials
3. Field scale implementation of steel slag for ground improvement
4. Durability of Steel slag stabilized geomaterials
5. Centrifuge and numerical modeling of structure/field scale steel-slag geomaterial implementation
6. Use of steel slags as an amendment for road base improvement
7. Investigating the use of steel slag in additive manufacturing

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Research Area 5: Design and Engineering Integration

Focus: Translate material behavior and performance into engineering design frameworks, enabling the safe and effective use of steel slag in structural and infrastructure applications.

Outcome: Connect laboratory and field performance to design-level considerations, ensuring compatibility with existing engineering practice and supporting inclusion in standards and specifications.

Topics of Interest:

Structural Performance and Design-Level Implications - Evaluate how steel slag incorporation affects the behavior of structural systems, including:

- Strength development and stiffness characteristics
- Serviceability and ultimate limit states
- Durability-related design considerations (e.g., exposure classes)

Computational Modeling and Simulation - Develop and apply numerical models (e.g., finite element analysis) to:

- Simulate structural performance of systems incorporating slag materials
- Compare behavior with conventional materials
- Evaluate sensitivity to material variability and performance assumptions

Design Guidance Development - Translate findings into:

- Practical guidance for engineers and designers
- Design inputs and parameters for use in standard practice
- Recommendations to support eventual integration into design codes and guidelines

Potential Projects:

1. Structural Limit State Response through Computational Analysis
2. Development of Design Guidance for Steel Slag Concrete Systems
3. Development of an element scale constitutive model for stabilized geomaterials
4. Thermodynamic Modeling to Predict Phase Formation in Activated Steel Slags

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Research Area 6: Policy, Implementation, and Decision Support

Focus: Enable practical adoption of steel slag in transportation infrastructure by evaluating economic and environmental feasibility, supporting specification development, and providing tools to guide decision-making.

Outcome: Translates technical findings into actionable guidance for DOTs, designers, and industry stakeholders to support implementation at scale.

Topics of Interest:

Lifecycle Cost and Environmental Analysis - Evaluate the overall feasibility of steel slag applications by considering:

- Material sourcing, processing, and transportation costs
- Construction and maintenance requirements
- Environmental impacts, including CO_2 emissions and potential benefits (e.g., carbonation)

Decision-Support Tools and Frameworks - Develop practical tools to assist stakeholders in selecting appropriate applications, including:

- Screening frameworks based on performance, cost, and availability
- Decision trees to guide material selection and use cases

Policy and Specification Recommendations - Provide guidance to support broader adoption through:

- Recommendations for ASTM, AASHTO, and state DOT specifications
- Identification of regulatory barriers and pathways for classification (e.g., co-product vs. waste)
- Support for transitioning toward performance-based specifications

Potential Projects:

1. Feasibility and Lifecycle Analysis for Steel Slag Applications
2. Policy Recommendations for Implementation of Steel Slag Activation Technologies
3. Slag market and supply chain logistics modeling
4. Business case assessment of steel slag in asphalt concrete
5. Development of a decision support tool for slag marketability

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This brief summarizes the Research Plan for the Industry Assessment for USDOT-SLAG, "Research Initiative on the Use of Steel Slag in Concrete and Cement" under cooperative agreement 693JK42550005. Information supporting these findings can be found at: https://cait.rutgers.edu/usdotsteelslag/publications/. Inquiries about this work can be sent to: usdotsteelslaginitiative@rutgers.edu.