

# Development of Engineered Cementitious Materials for Railroad Crossties

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## Motivation

Durability is a critical factor for concrete railroad crossties. Despite AREMA requiring minimum 10 years of the life cycle, complex loading conditions (e.g., impact) and the associated damage can severely accelerate durability issues. While it is necessary to specify the detail of structural and durability loadings, a prescriptive resolution is to develop “stronger” and “durable” concrete. However, the economic factor cannot be ignored as considering the crossties are mass produced. Thus, this research is to develop effective high-performance cementitious materials tailored to the concrete crossties by highlighting: (1) **higher structural performance (mechanical property and impact resistance)**, (2) **higher resistance to chemical attacks (corrosion)**, and (3) **minimal abrasion damage**.

## Mixture Design Criteria

### AREMA Quality Control Requirement:

- Over than 7,000 psi at 28 days
- Minimum service life: 10 years
- Highly resistant to Alkali aggregate reactivity, Delayed ettringite formation, freeze-and-thaw, and corrosion.

### This research:

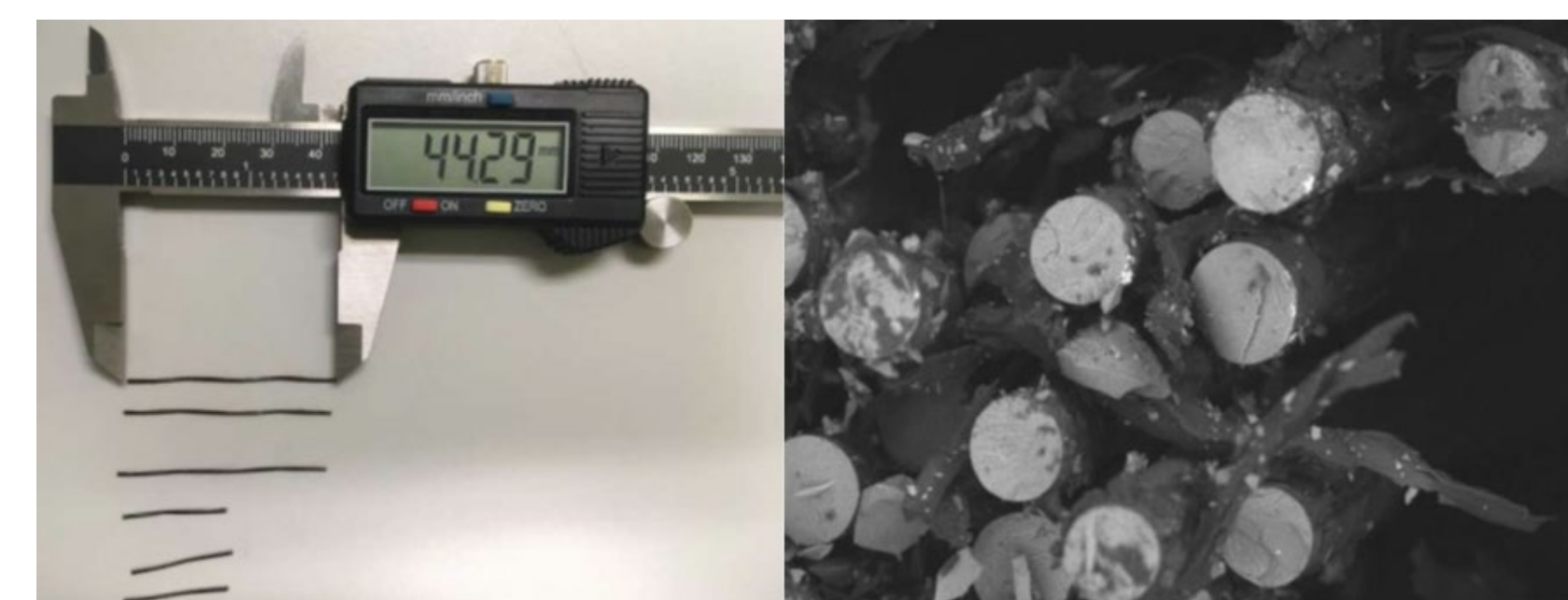
- Paste content not exceed than 35% by volume.
- Ternary cementitious matrix (Cement, Silica Fume, and Ground Granulated Blast Furnace Slag)
- Use of Non-metallic fiber
- Consideration of aggregate angularity
- Minimum target slump: 3 in.

### The expected performances are:

<b>Strength:</b>	<ul style="list-style-type: none"> <li>• Over than 10,000 psi at 7 days without steam-curing. (Energy efficiency)</li> <li>• High impact resistance.</li> <li>• Increase toughness. (resistance to crack propagation)</li> </ul>
<b>Durability:</b>	<ul style="list-style-type: none"> <li>• Minimize the diffusion rate of chemicals. (prevent ASR, DEF and potential Freeze &amp; Thaw)</li> </ul>

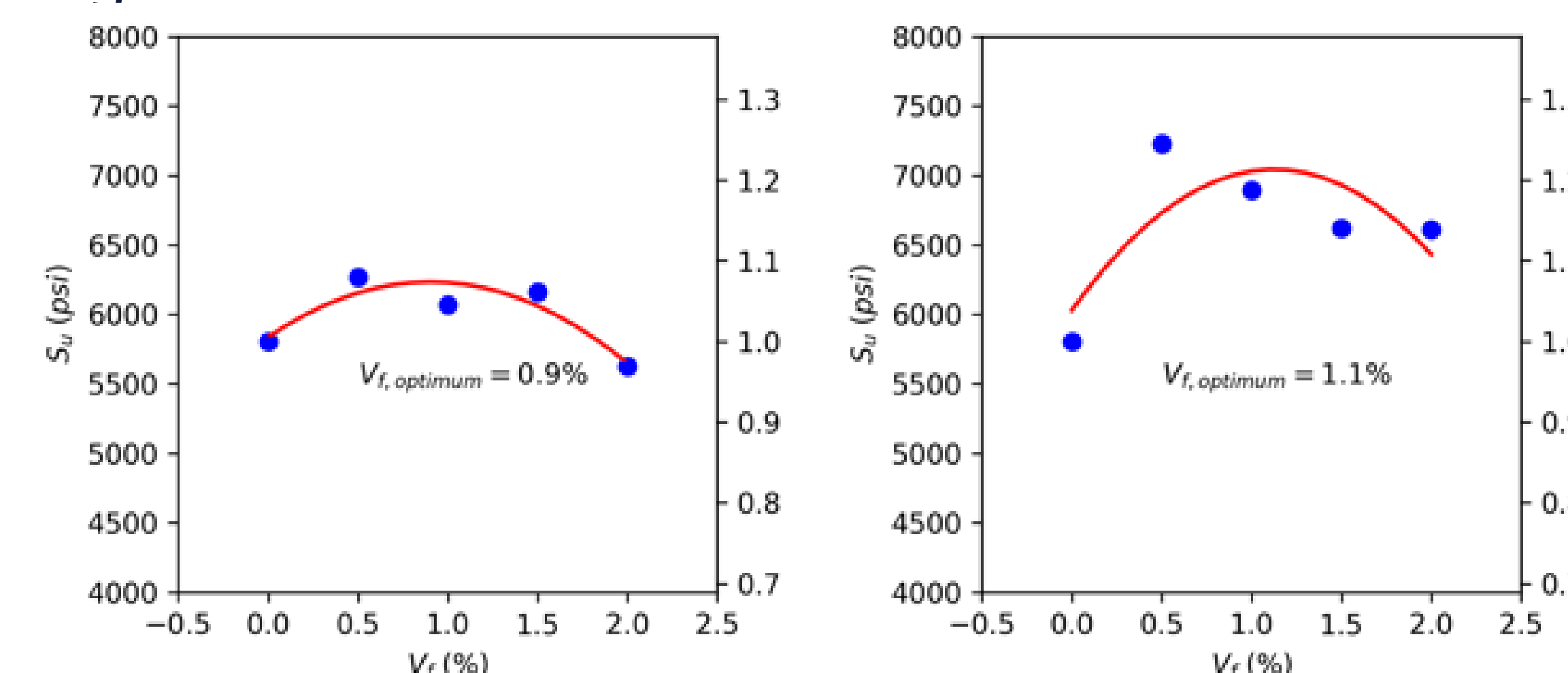
## Optimization of Fiber Contents

- Use of Non-Metallic Fiber minimizes the corrosion as compared to metallic fibers.
- Basalt fiber (so-called “Minibar”) content is optimized.



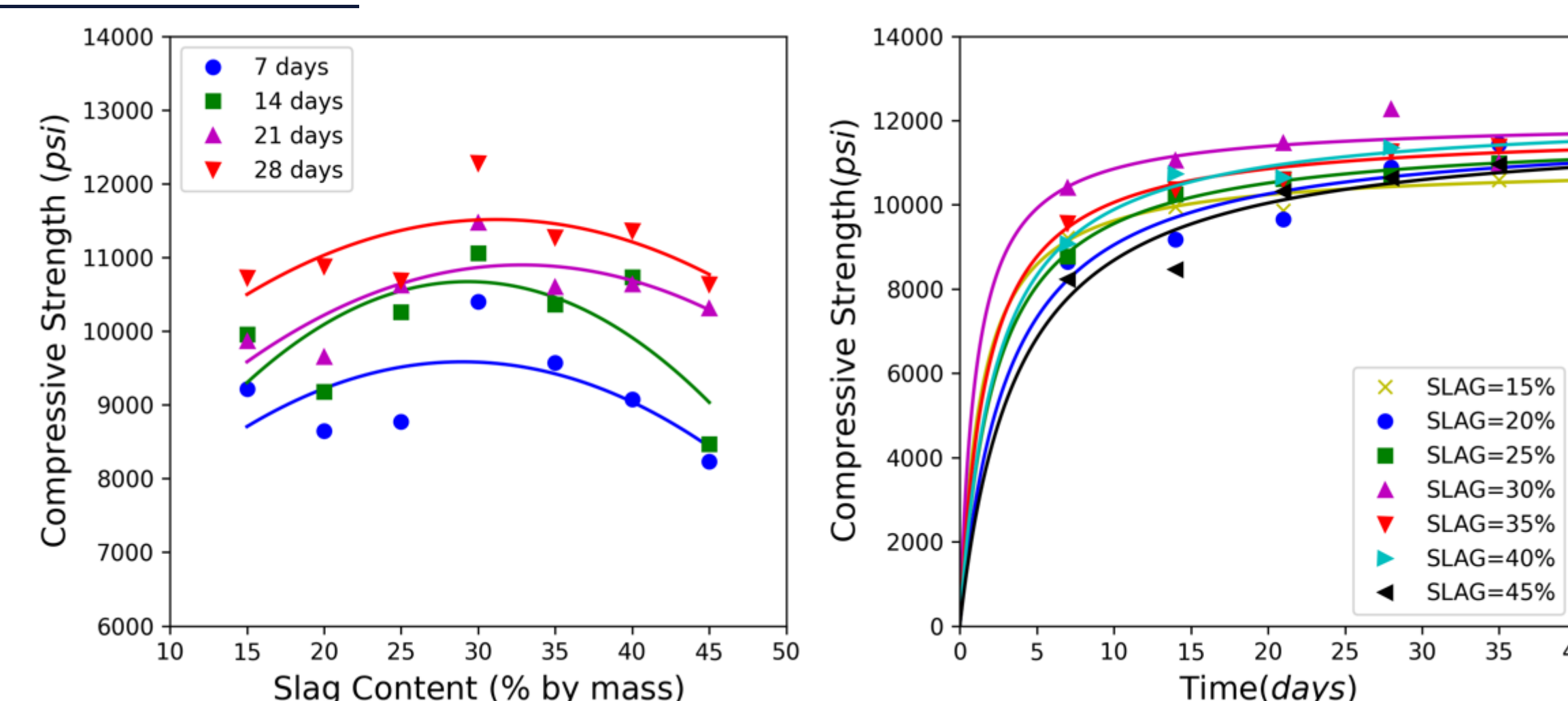
Two different lengths (i.e. 43mm and 20mm) are tested. (Left) and SEM images confirm fibers coated by thermoset resins. (improve friction)

- **0.9% to 1.1%** by volume produced the highest compressive strength.



## Optimization of Ternary Mixture

- The content of Ground Granulated Blast Furnace Slag (GGBFS) is optimized.
- **15% of cement is replaced by Silica Fume** as default.
- **Higher contents of GGBFS** leads to **improvement of cost benefit, durability performance, and structural performance**.

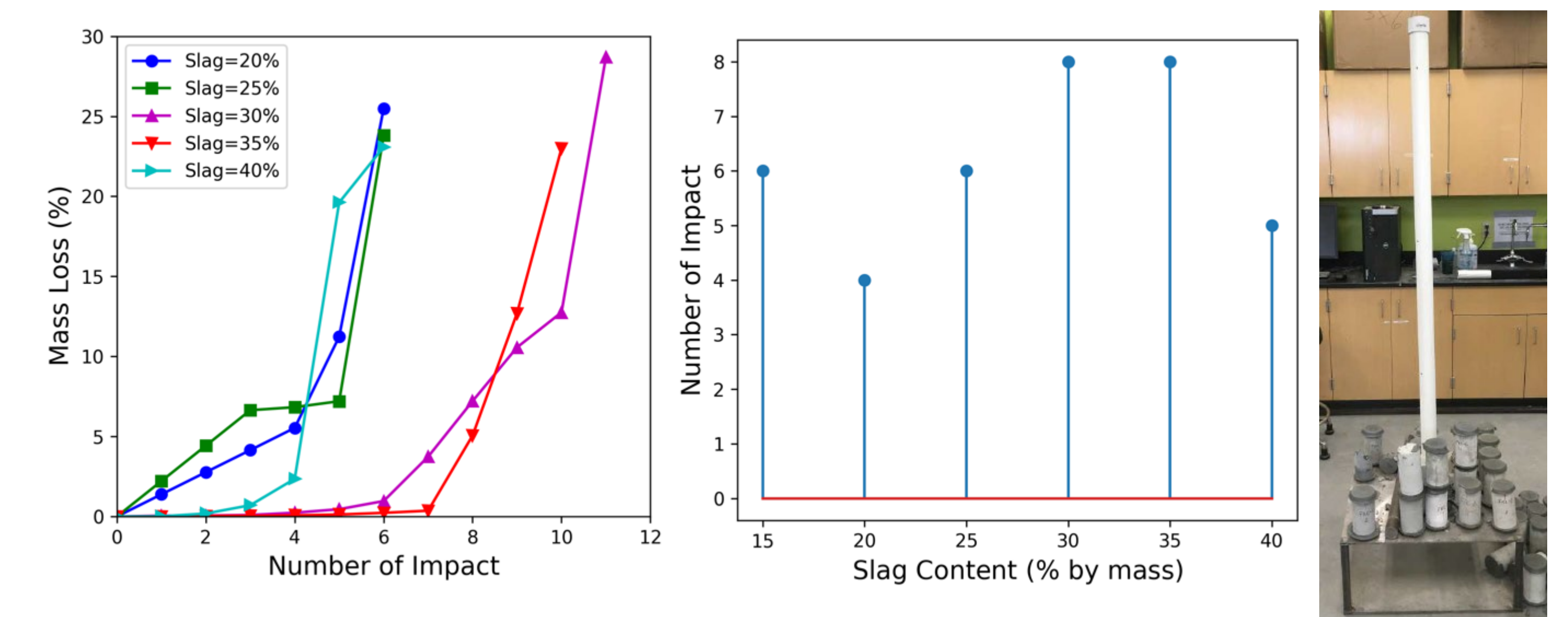


- All mixture designs tested in the research produced over 9,000 psi at 7 days without steam curing. (Meet AREMA requirement with significant energy saving.)
- **30 to 35% of GGBFS replacement produced the highest strength.**

## Evaluation of Impact Resistance

Semi-Quantitative Impact resistance is established:

<b>Quantitative: (Left)</b>	• Measure mass loss of the specimen at each 18lb hammer hit from 70 in.
<b>Qualitative: (Right)</b>	• Measure the number of 18lb hammer hit from 70 in. height until no rebound occurs.



The Impact Hammer Testing Apparatus (Right)

- **30-35% GGBFS contents** showed the best performance in impact resistance.

## Evaluation of Durability

- Accelerated Corrosion Test qualitatively showed better corrosion resistance as compared to the normal concrete (i.e., 4,500 psi concrete).



Engineered Cementitious Materials (Top) and Normal Concrete (Bottom); No crack / Visible leakage of  $\text{Fe}(\text{OH})_2$  is observed in ECM, while splitting failure occurs at 3 days.

## Future Research

- Surface Smoothness will be evaluated by measuring Light Reflectance on the surface.
- Thus, light reflectance can be used for an indicator representing abrasion resistance.

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