Physico-chemical Characteristics of Electric Arc Furnace and Caster Slags and Their Potential for Soil Stabilization

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Motivation

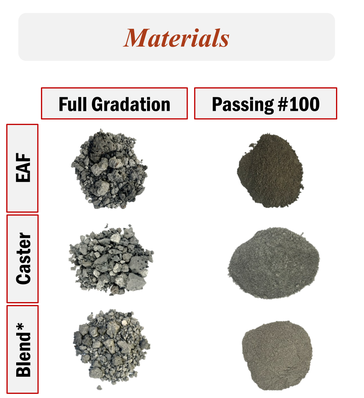
- Soil stabilization using chemical additives is a proven technique for enhancing the strength and performance of weak subgrade soils.
- Incorporating alternative materials like steel co-products can improve resource efficiency and reduce environmental burdens.
- Electric Arc Furnace (EAF) slag has shown promise for use in pavement construction with favorable physical and chemical properties.
- However, EAF slag properties can vary with scrap and processing, which can affect the soil stabilization and improved performance.
- Advanced EAF characterization tests can be linked to soil stabilization mechanisms, allowing a clearer assessment of sample-dependent efficacy of slags in geotechnical applications.

Objectives

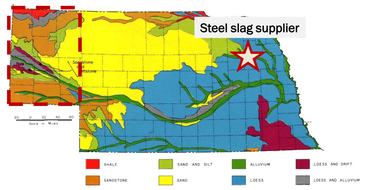
- Perform a holistic (physical, chemical, mineralogical, morphological, and mechanical) characterization of selected steel slags (EAF and Caster slags).
- Link different slag properties with potential stabilization mechanisms (cation exchange, particle restructuring, and/or pozzolanic reactions).
- Determine the effectiveness of the studied slag in improving the mechanical performance and swelling behavior of soils.
- Verify if the combined use of slag and Portland cement can enhance slag stabilization potential.

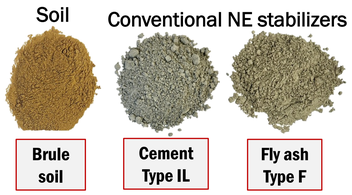
Methodology

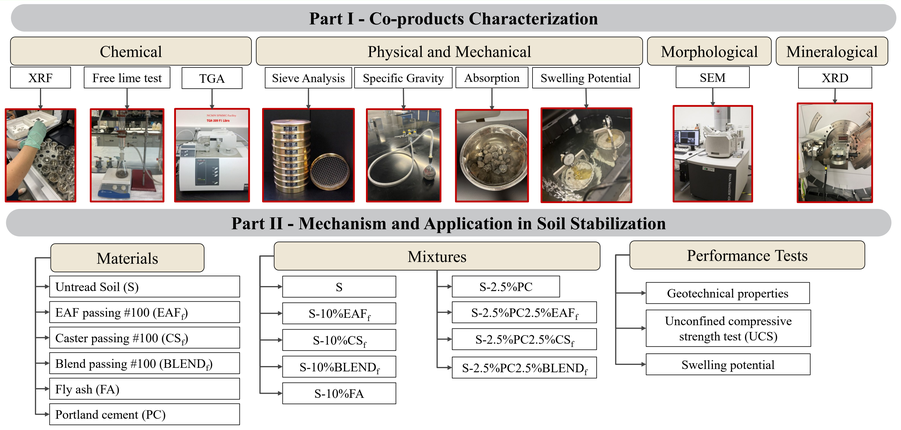
Materials



*The blend consists of ~75% EAF and ~25% caster slag.







Part I - Slag Characterization Results

Chemical

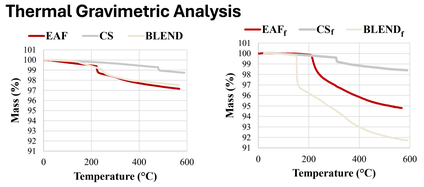
Free lime content

Free lime					
Sample	EAF	Caster	Blend	Cement (Liu et al., 2020)	Fly ash (Kaewmanee et al., 2013)
Free lime (%)	**0.81%**	**0.86%**	**0.46%**	0.3% - 3.3%	0.8% - 2.1%

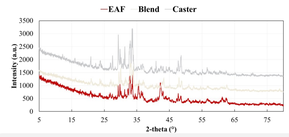
X-ray fluorescence

XRF			
Chemical Composition (%)	EAF	Caster	Blend
CaO	35.12	52.154	43.574
SiO2	17.77	28.006	21.373
MgO	10.54	7.442	9.1245
Fe2O3	18.88	4.894	7.797
Al2O3	5.92	3.704	6.7665
Mn2O3	4.13	1.097	1.6685
SO3	0.95	1.498	1.6785
Cr2O3	0.96	0.191	0.273
TiO2	0.30	0.181	0.2355
ZnO	0.53	0.019	0.361
Na2O	0.23	0.045	0.179
P2O5	0.19	0.045	0.074
K2O	0.11	0.035	0.0745
SrO	0.05	0.046	0.0415
S	0.01	0.03	0.03
LOI	4.72		7.015

Thermal Gravimetric Analysis



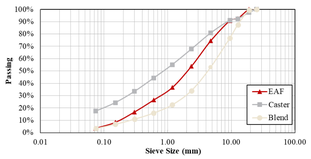
Mineralogical



- **EAF**
  - β-C2S(Ca_2SiO_4)
  - Belite (Ca_2SiO_4)
  - Alite ($3CaO{\cdot}SiO_2$)
  - Gehlenite ($Ca_2Al_2SiO_7$)
  - Magnetite (Fe_3O_4)
- **Caster**
  - Calcio-olivine (Ca_2SiO_4)
  - Calcite ($CaCO_3$)
  - Ferrite (Fe_2O_4)
  - γ-C2S (Ca_2SiO_4)
  - Gehlenite ($Ca_2Al_2SiO_7$)
- **Blend**
  - β-C2S(Ca_2SiO_4)
  - Belite (Ca_2SiO_4)
  - Calcite ($CaCO_3$)
  - Gehlenite ($Ca_2Al_2SiO_7$)
  - Periclase (MgO)

Physical and Mechanical

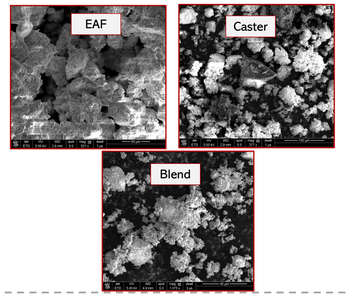
Sieve Analysis (ASTM C136)



Absorption (ASTM C127) and Specific Gravity (D854)

Sample	EAF	Caster	Blend
Specific gravity (Fine)	3.09	2.86	3.03
Specific gravity (Coarse)	3.05	2.82	2.99
Absorption	3.5%	4.4%	2.6%

Morphological

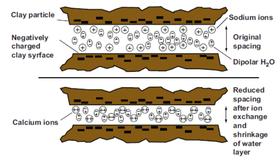


Part II – Soil Stabilization Results

Geotechnical Properties

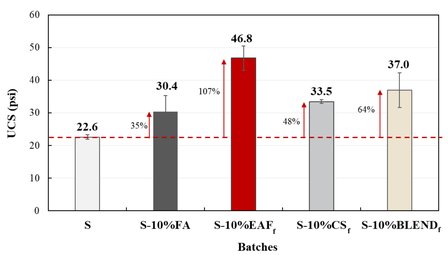
Atterberg Limits and Optimum Moisture Content (OMC) (ASTM D4318 &D698)

Sample	Dry density (g/cm³)	OMC	Soil classif.	Liquid Limit (%)	Plasticity Limit (%)	Plasticity Index
S	1.88	19.7%	A-6 / ML	36.17	24.93	11.24
S-10%BLEND	1.96	19.2%	-	33.92	26.97	6.95
S-10%CS	1.95	20.1%	-	30.41	23.72	6.69
S-10%EAF	1.98	19.2%	-	34.37	27.66	6.72
S-10%FA	1.92	20.6%	-	-	-	-
S-2.5%PC	1.84	22.2%	-	-	-	-
S-2.5%PC2.5%EAF_f	1.87	23.0%	-	-	-	-
S-2.5%PC2.5%$BLEND_f$	1.87	23.2%	-	-	-	-

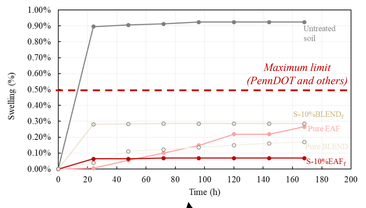


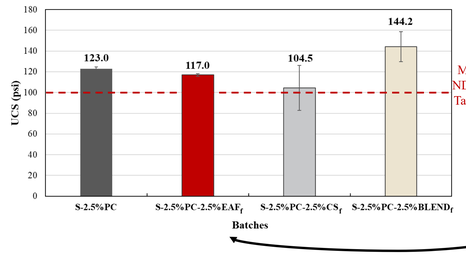
Mechanical Tests

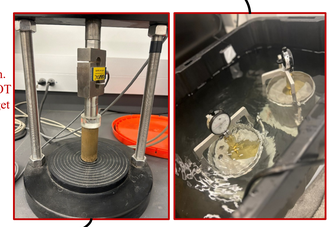
Unconfined compressive strength test (ASTM D2166)



Swelling Potential (ASTM D4792)







Conclusions

- XRD, TGA, and free lime tests were effective in distinguishing the three slags from each other, highlighting their possible stabilization mechanisms.
- The slags improved some properties of the soil, reducing the plasticity index and increasing density.
- Each slag significantly outperformed untreated soil and fly ash in the 7-day UCS test.
- The results suggest that different slags may activate distinct stabilization mechanisms, which could lead to varying performance outcomes when applied to other soil types.
- *Future works:* This research will be expanded using different soil types and curing periods. Additionally, other mechanical tests will be performed, such as resilient modulus and fracture tests.

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