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Current Research Areas:
SUSTAINABLE MATERIAL USING GEOPOLYMER & BIOPOLYMER

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A throwback:

The Spread of Human Populations, c. 10,000 B.C.E.

- Early human civilisations grew on the shores of rivers thanks to the abundance of varieties of natural resources, and most importantly water.
As such, one of the major challenges that primitive human faced was controlled usage of water for irrigational purpose pertaining to agriculture. Floods were also not very uncommon, that led to designing of simple water retaining structures such as leaves and dykes (Holtz and Kovacs, 1981) which may be adjudged as a precursory equivalent of modern day dams.
These structures were associated with number of geotechnical concerns such as stability of slope, failure of foundations, seepage etc. that often resulted in catastrophic consequences. Every failure served as a keystone of learning, and the subsequent designs are based on experience from past. Thus, incipient days of geotechnical engineering relied significantly on experience and empirical approaches (Terzaghi et al. 1996).
Highly nonhomogeneous and site specific properties of earth materials makes the job of the geotechnical engineer even more complicated, and no wonder Holtz and Kovacs (1981) chose to classify it as an ‘art’ rather than a branch of engineering science.

- late 1700’s when Coulomb’s theory of earth pressure came to existence enabling treatment of the subject with a scientific approach.
- Further, theoretical formulations for retaining walls, embankments were developed by Rankine (1857) and Culman (1875).
- Darcy (1856) developed fundamental understandings of flow of water through permeable materials such as sand.
- Pioneering concepts by Boussinessq (1885) on stress distribution underneath a loading area and Mohr’s failure criterion (1900) further advanced the knowledge in the field.
- Swedish scientist Atterberg (1911) came up with simple tests for determining consistency of cohesive soils which is still being practiced.
- The word ‘Geotechnical’ as used widely today, was coined by the Swedish Commission.
- Early 20th century also witnessed publication of the first known textbook in the field erdbaumechanik (English: Soil Mechanic) by Prof. Karl Von. Terzaghi, who is well known as the father of soil mechanics and geotechnical engineering.
A throwback:

- Last 300 years of soil mechanics and geotechnical engineering focused on physical, chemical, geological and mineralological aspects to advance the understandings of engineering behaviours of soil (Mitchell and Santamarina, 2005).
- Simplified two phase idealisations for saturated (soil-water) or dry (soil-air) soils, and rather complicated but realistic unsaturated behaviour of soils with three phased models are captured with concurrent occurrence of moisture and air in pore space of soil skeleton.
- Concepts and mathematical formulations pertaining to three phased treatments of geomaterials are well established.
- However, these treatments regard biological phase to be inert.
Mine overburden/tailings as geomaterial
Cementitious material/ geopolymer

Environmental sustainability

Financial feasibility

Technical suitability

Classification of types of cementitious material

Every ton of Portland cement production requires 1.5 tons of raw materials i.e. limestone and soil (Rashad, 2014). Releases 0.95 ton of CO2 (~5% of manmade CO2 emission) (Ludwig and Zhang, 2015).
Controlled low strength material using coal mine overburden
Potentials of biological mediation in Geotechnical Engineering (Dejong et al. 2010)

Field trials of microbial aided calcite precipitation (Van Paassen 2011)

Mishra, Das and Mohanty (2017)

Chenu and Stotzky (2002), microbes may inhabit inside or on the walls of saturated and unsaturated pores space in soil.

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\begin{align*}
\theta_{lm} &= \frac{V_{lm}}{V_v} \\
S &= \frac{V_w}{V_v}
\end{align*}
\]

\[
V_v = \begin{cases} 
V_w; S = 1, \theta_{lm} = 0 \\
V_a; S = 0, \theta_{lm} = 0 \\
V_{lm}; S = 0, \theta_{lm} = 1 \\
V_w + V_a; 0 < S < 1, \theta_{lm} = 0 \\
V_a + V_{lm}; S = 0, 0 < \theta_{lm} < 1 \\
V_w + V_{lm}; 0 < S < 1, 0 < \theta_{lm} < 1, S + \theta_{lm} = 1 \\
V_w + V_a + V_{lm}; 0 < S < 1, 0 < \theta_{lm} < 1, S + \theta_{lm} < 1 
\end{cases}
\]
Dust control in mining areas

Penetration surface of shale sample treated with (a) water (b) 1% of guar gum solution

Wind Erosion test of shale (Highly erodible)

Cylindrical dispersion test of shale sample treated with biopolymer

Dispersion (pinhole) test (ASTM 4647)
CHALLENGES

ACID MINE DRAINAGE
Thank you for your support!