Transport
Research Centre

Sustainable Use of Recycled Crushed Glass for Soft Railway Subgrade Improvement

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Current challenges

Track degradation

Full list of upcoming repair disruptions

By 9News Staff | 12:53pm Jul 13, 2023

Buses replace trains across network

Sydney T

by News Desk — June 2

Buses replace trains: is Sydney doomed to endure the curse of weekend trackwork forever?

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are ahead

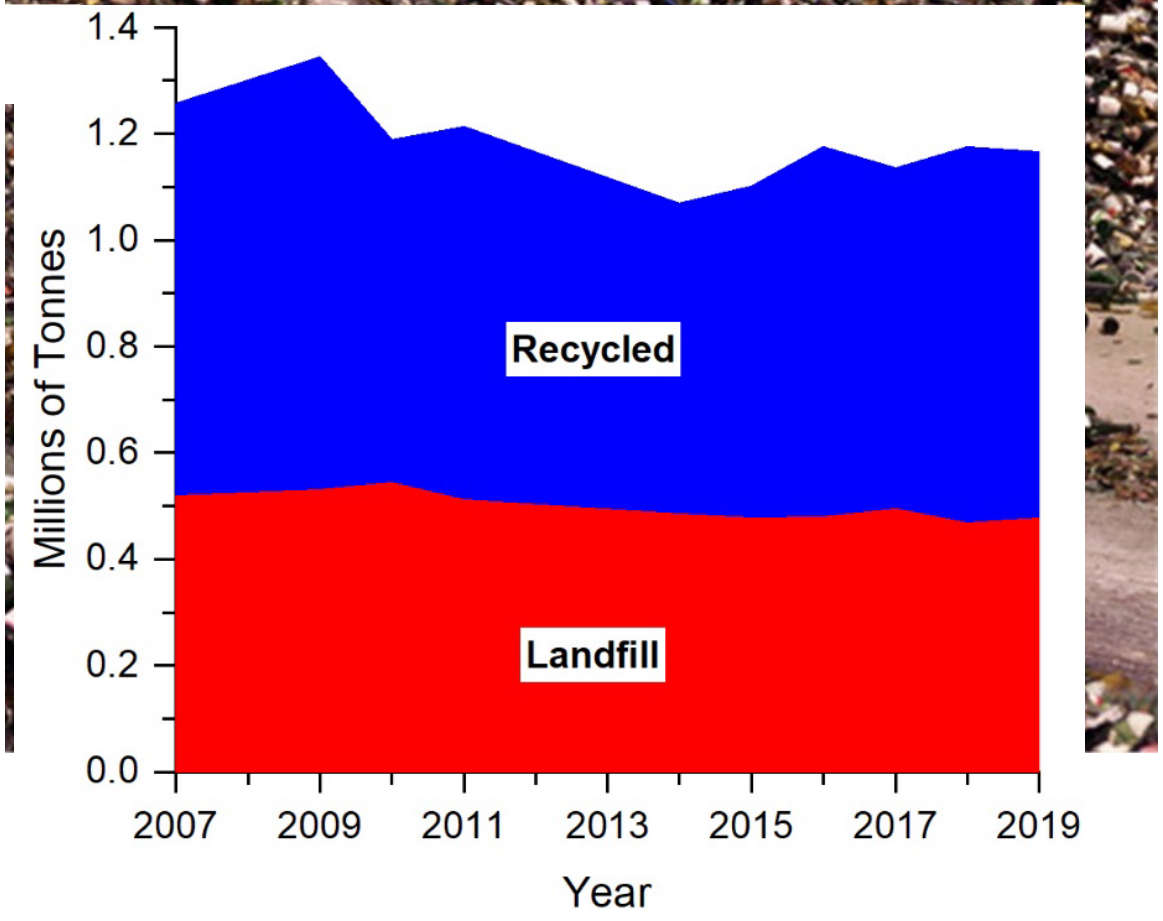
ATED: 08:48 AEST, 20 July 2023

this Weekend

Current challenges

Glass waste management

- Destination of glass waste in AUS



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technology environment

Australia's reliance on sending waste overseas for recycling is fuelling a crisis in the industry

Australia's appetite for sending waste overseas for recycling has created a huge problem that we are running out of time to fix.

Charis Chang CharisChang2 22 comments news.com.au NOVEMBER 15, 2019 3:11PM

After China introduced its recycling restrictions, companies that couldn't find somewhere else to send their recycling were forced to stockpile the materials, creating a potentially hazardous situation.

There have been a number of fires at recycling facilities in the past few years including one massive blaze at a Melbourne warehouse that eventually saw one of Australia's biggest recyclers, SKM, go into receivership.

The 2017 fire at SKM's Coolaroo warehouse in Melbourne where piles of glass were stored. Picture: Seven

Background

Increasing demand for efficient freight and passenger rail network → Heavier and faster trains → Challenging ground conditions → Faster track degradation

Track Degradation

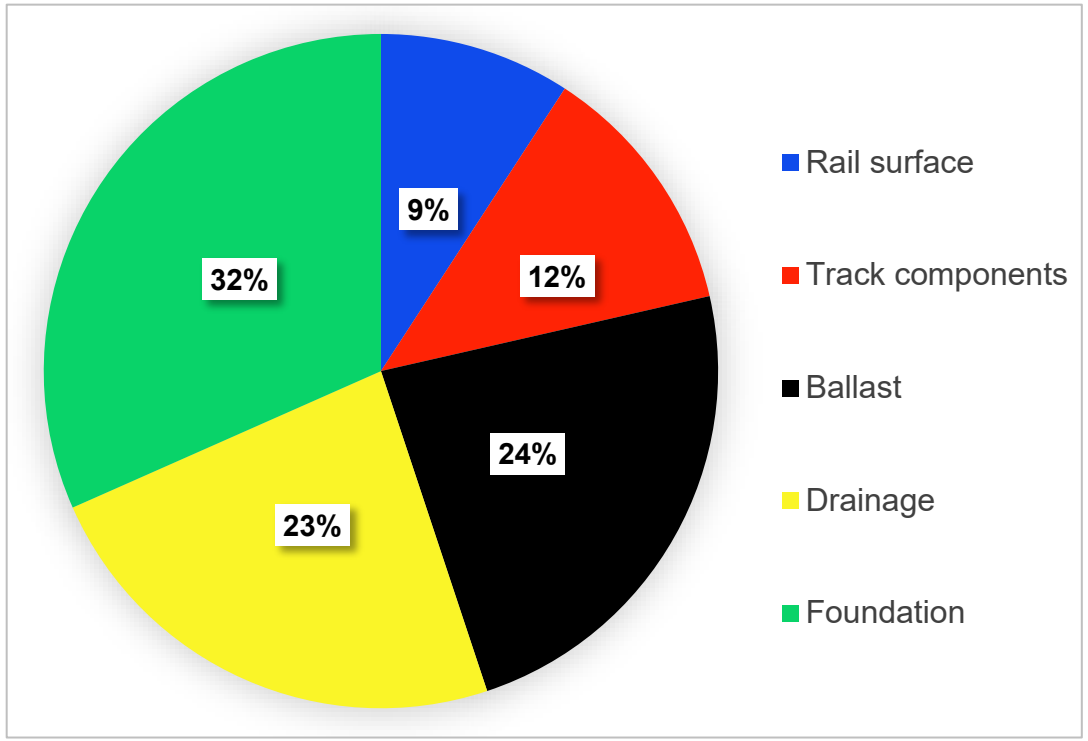
Mud Pumping

Excessive Settlement

Track misalignment

Ballast degradation

Influence of track components on track deterioration



(UIC 2008)

Background

Measures for subgrade improvement

No.	Solution	References
1	Remove, replace and/or modify materials	Kuo et al. 2017; Li et al. 2016; Transport for NSW 2019
2	Improve drainage	Abeywickrama 2020; Indraratna et al. 2009; Nguyen et al 2018
3	Include geosynthetic composites	Alobaidi & Hoare 1998; Chawla & Shahu 2016; Hudson 2016
4	Mass stabilisation	Ahmad et al. 2012; Transport for NSW 2019; Voottipruex and Roongthanne 2003; Wheeler et al. 2017

Traditional methods:

- Chemical additives
- Environmental impact
- Carbon emission
- Effect on groundwater

Sustainable method:

- Recycled crushed glass (CG) mixed with subgrade soil

Waste glass transformed into sand-sized crushed glass

(iQRenew, 2021)

Background

Why using glass?

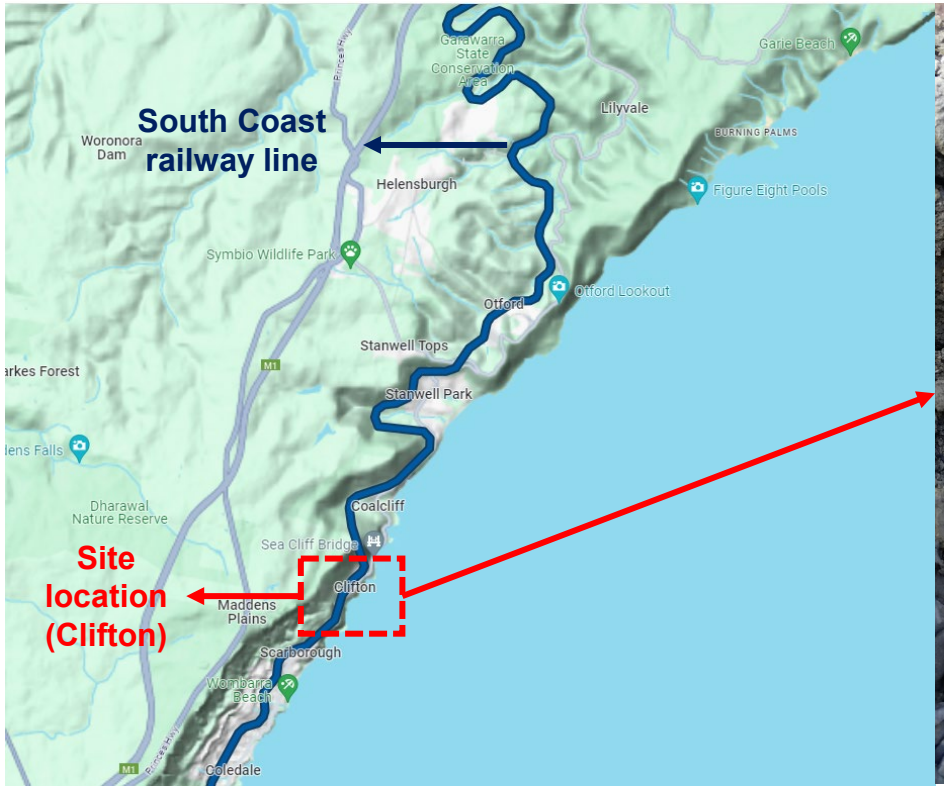
- Inert – no adverse effect on groundwater
- Decrease the demand for natural quarried materials
- Reduce construction carbon footprint
- Reduce glass waste diverted to landfills
- Flexible size range for different applications
- Angular particles promote interlock within the soil matrix

Objectives

- Address the challenges associated with soft subgrade soil in railway infrastructure by investigating the potential use of recycled crushed glass as a sustainable method of stabilisation
- Characterise the geotechnical properties and monotonic shear behaviour of CG and subgrade soil mixtures and determine the optimum CG percentage for practical applications

Materials and Methods

Soil samples

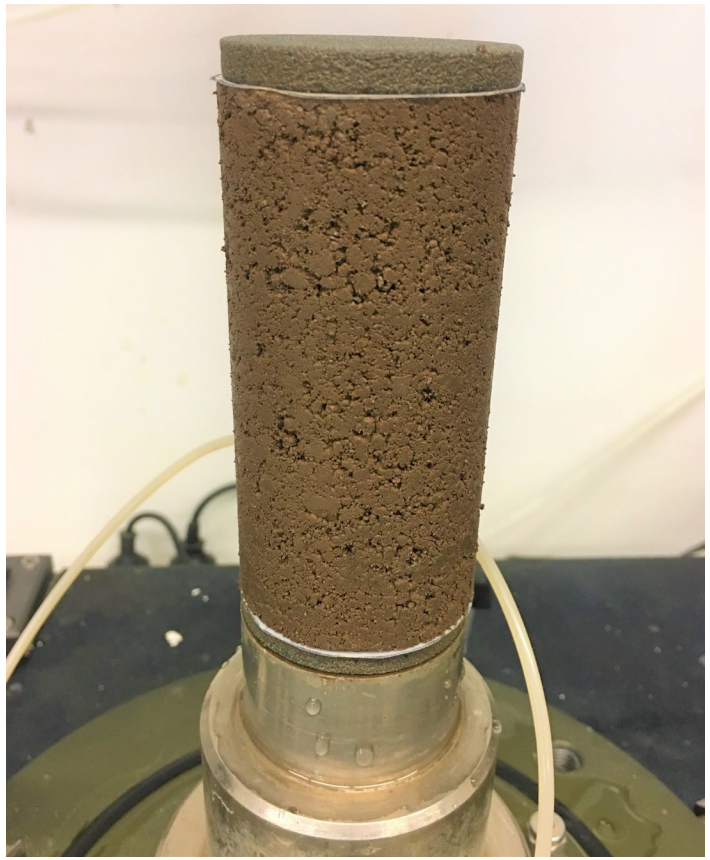


CG samples

- Rail track with high degree of fouling
- Depth of sample collection: 0.5 – 1 m
- CG samples obtained from local manufacturer

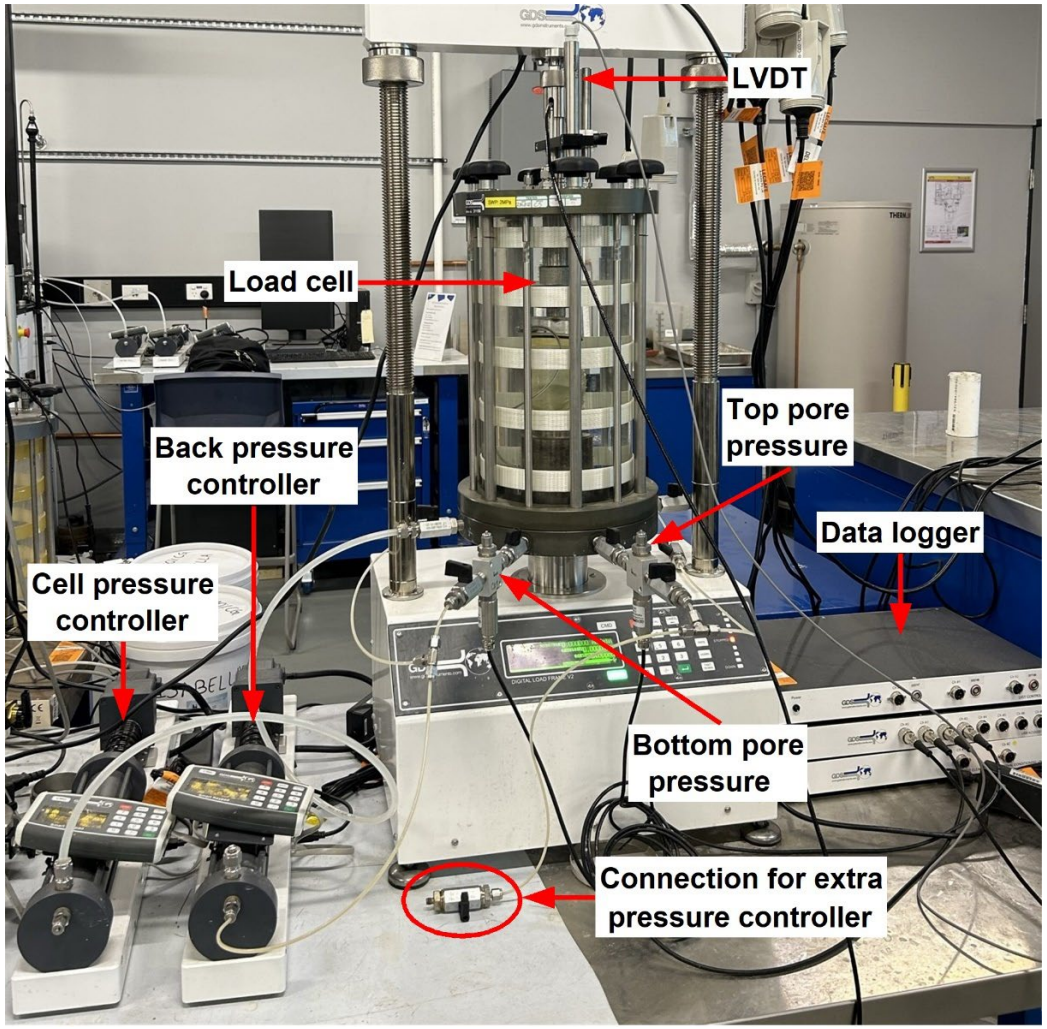
Materials and Methods

Soil specimen preparation



- RC = 95% $\gamma_{d,max}$
- *w* = 95% - 100% *wopt*
- CG content = 10%, 20%, 30% and 50%

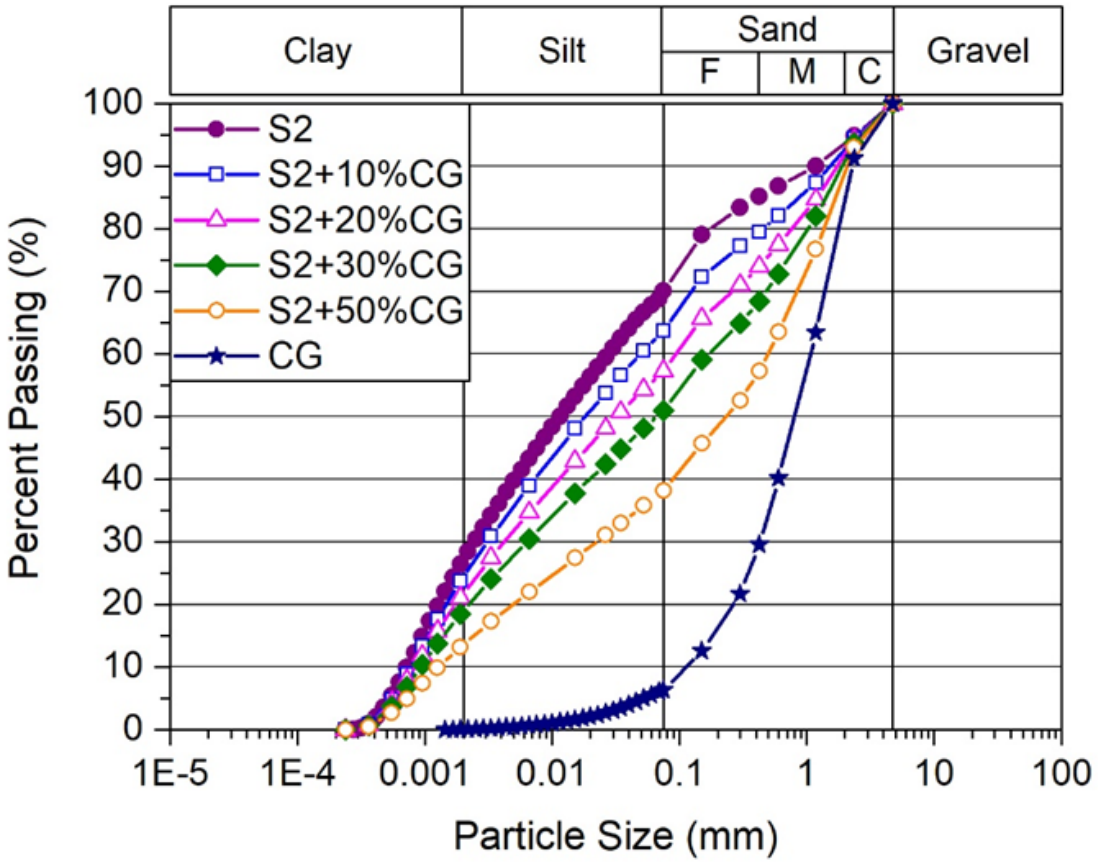
Investigation of shear behaviour

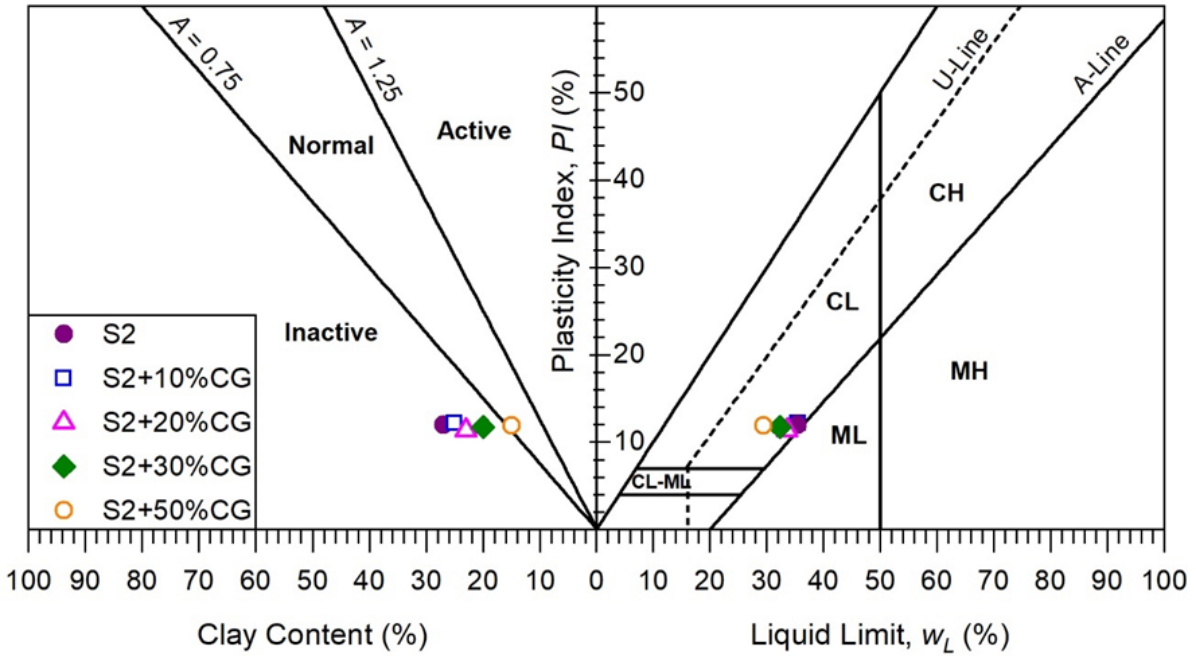


Results and Discussion

Material characterisation

- **CG content: 10%, 20%, 30% and 50%**

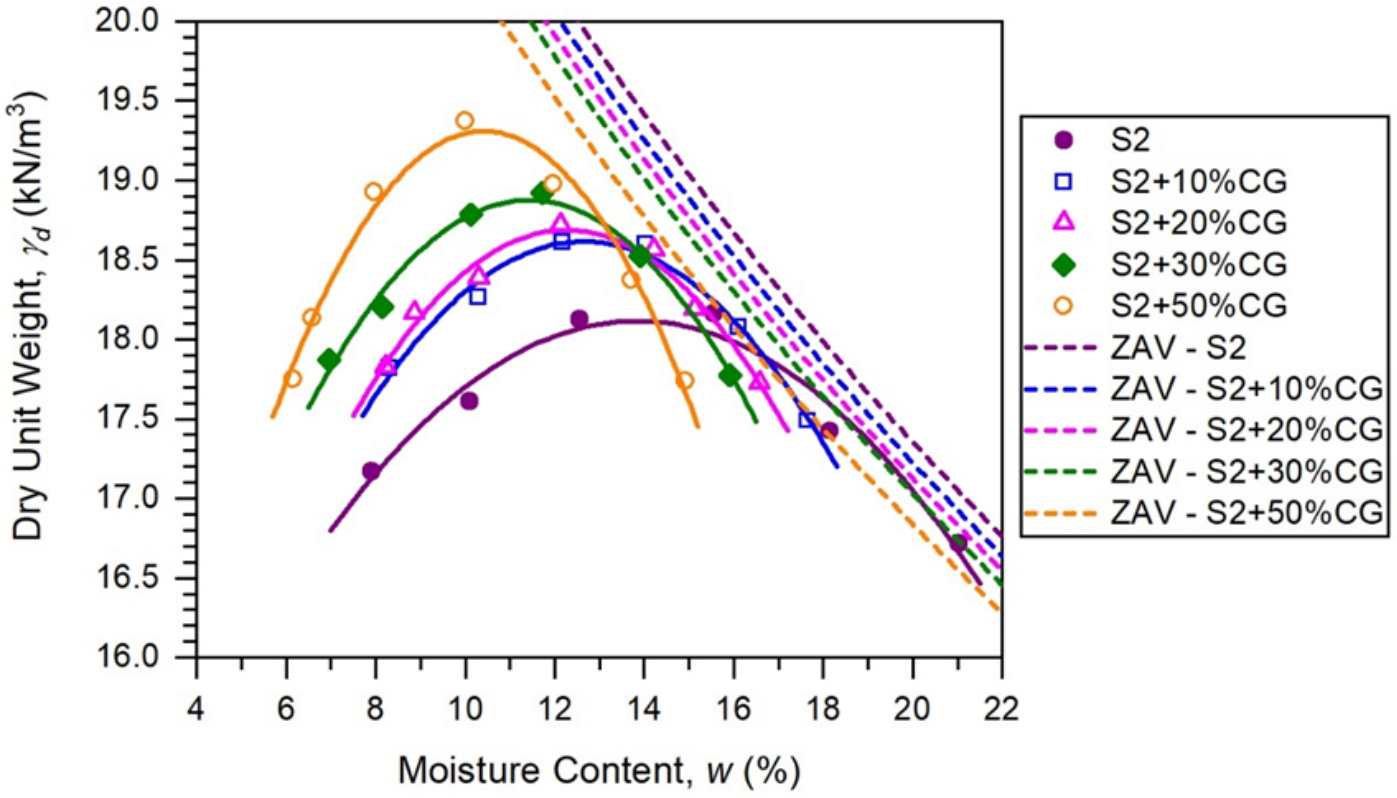


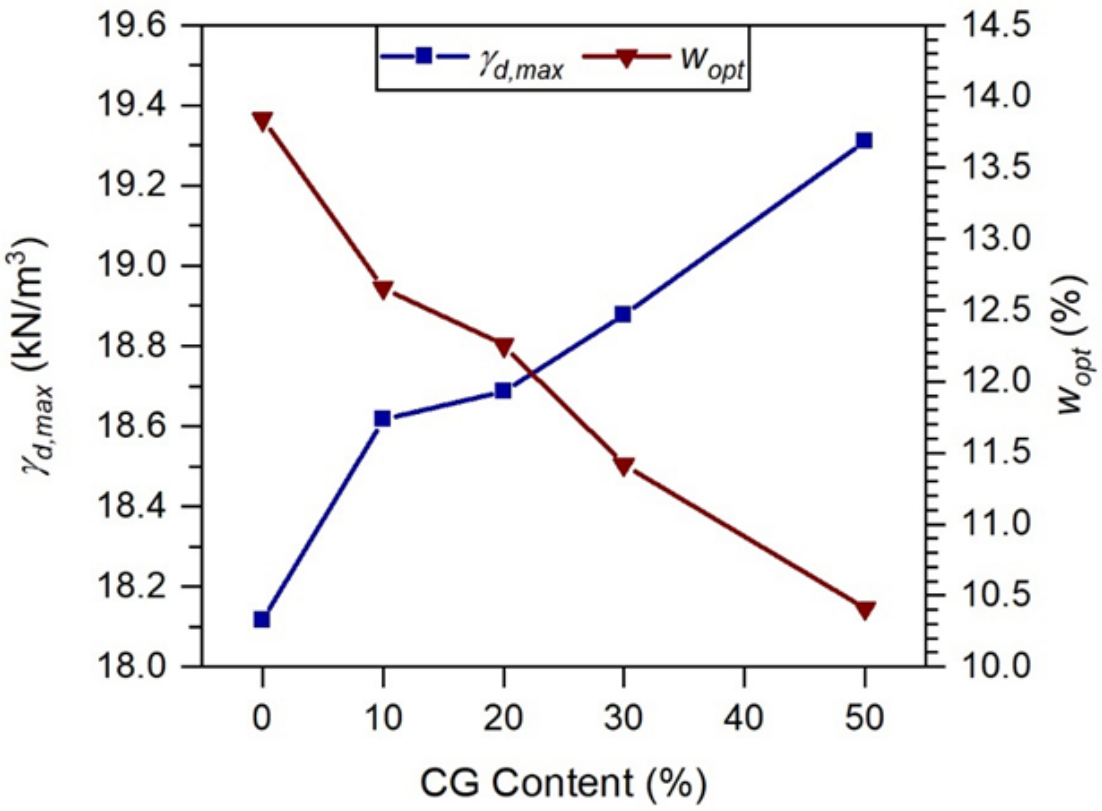


Material	Atterberg limits			USCS
	w_L (%)	w_P (%)	PI	
S2	35.5	23.5	12	CL
S2 + 10% CG	35.5	23.4	12.2	CL
S2 + 20% CG	33.6	22.1	11.4	CL
S2 + 30% CG	32.3	20.6	11.7	CL
S2 + 50% CG	29.4	17.6	11.9	SC
CG	-	-	NP	SW-SM

Results and Discussion

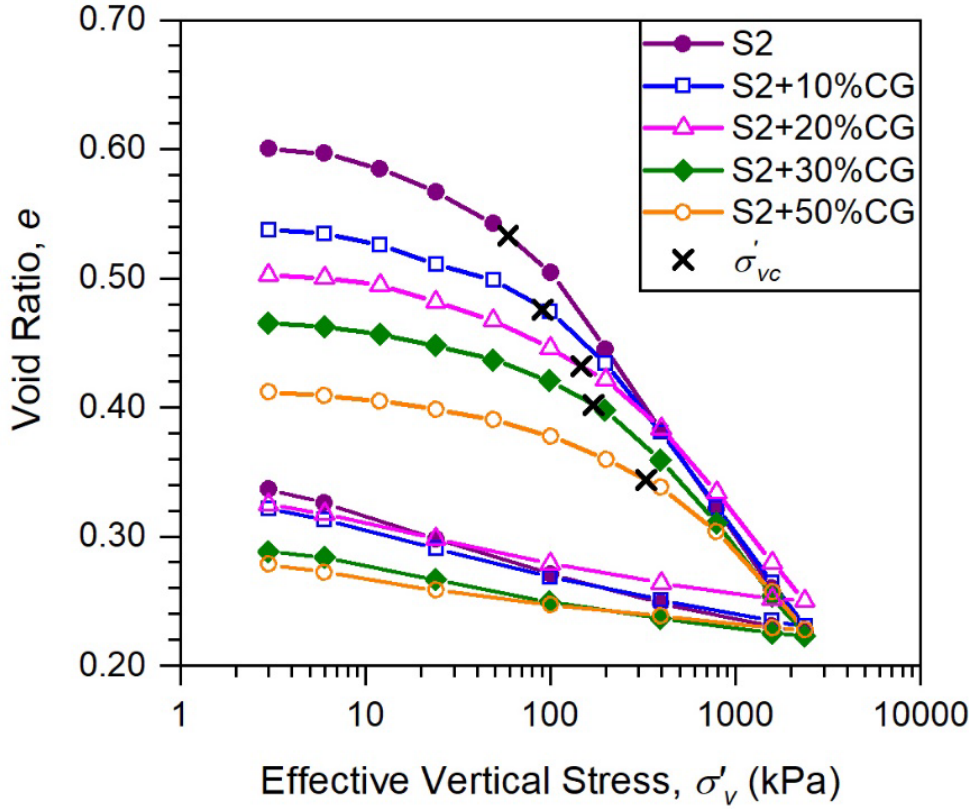
Compaction characteristics

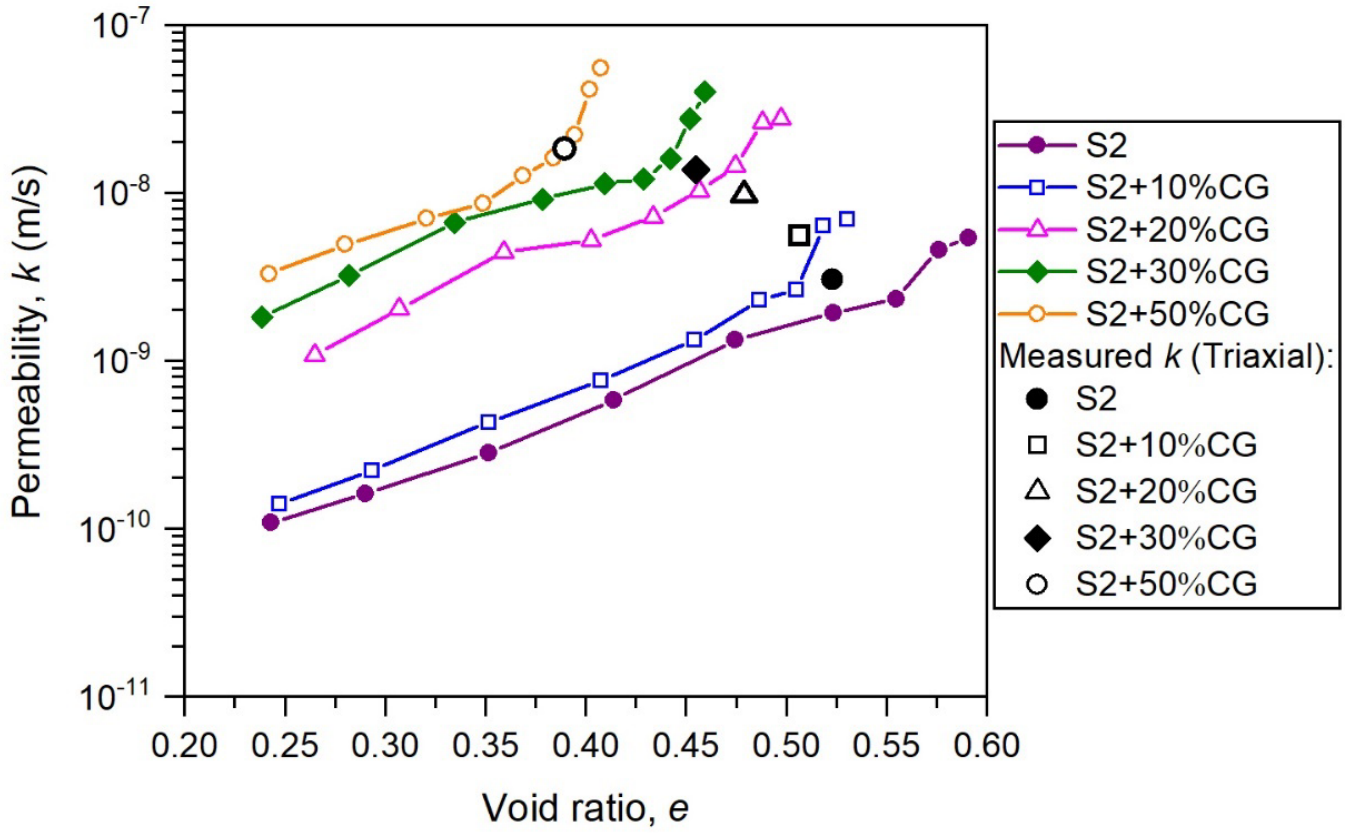




Results and Discussion

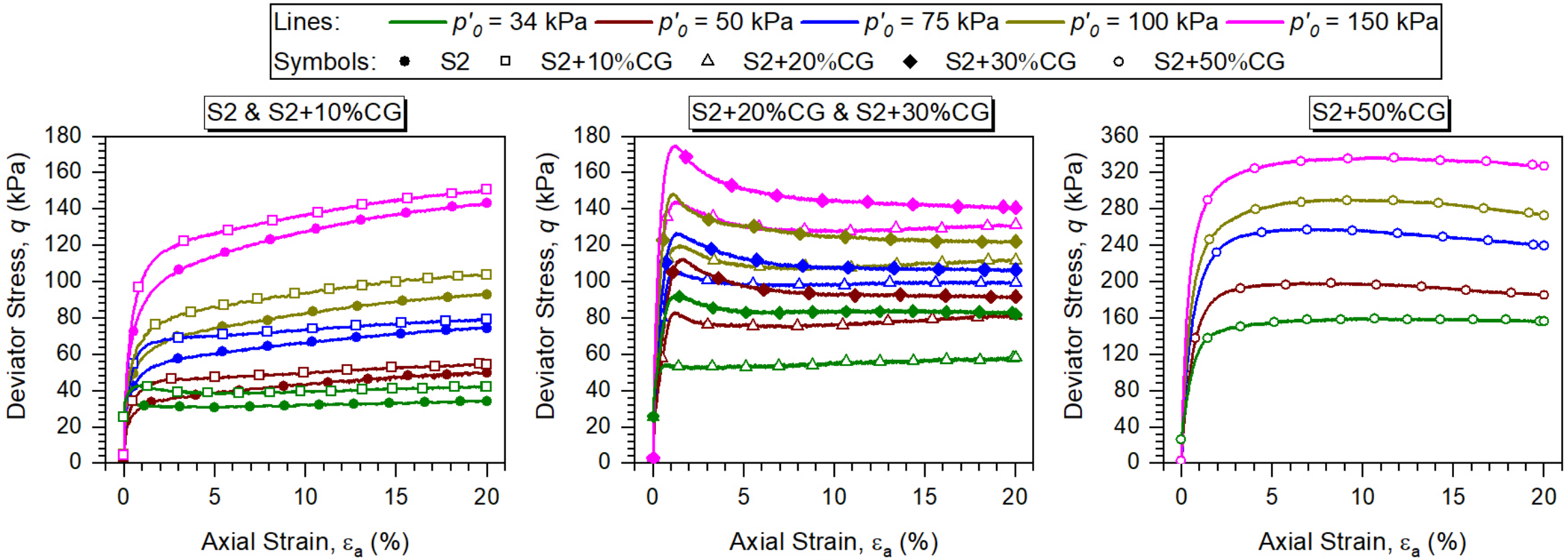
Consolidation and permeability





	S2	S2 + 10% CG	S2 + 20% CG	S2 + 30% CG	S2 + 50% CG
σ'_{vc}	59	91	148	171	329
C_c	0.206	0.189	0.177	0.175	0.160

Results and Discussion



- **S2 & 10%CG**

Strain hardening
Behaves like compacted clayey soil
Marginal shear strength improvement

- **20%CG & 30%CG**

Transitional behaviour depending on p' and CG
Behaves like silty sands and sandy silts

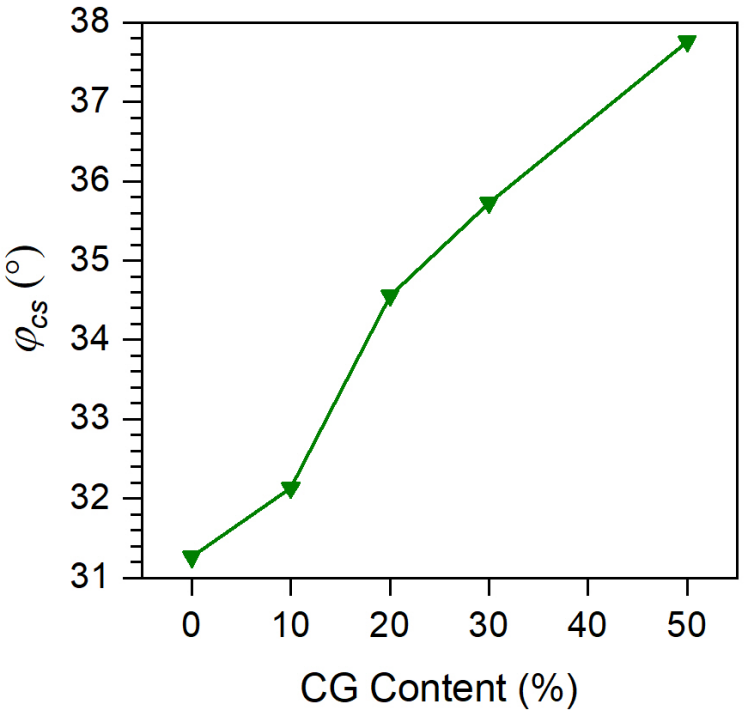
- **50%CG**

Behaves like dense sand
Compared to the 30%CG, the shear strength increased by over 70% regardless of the initial p'

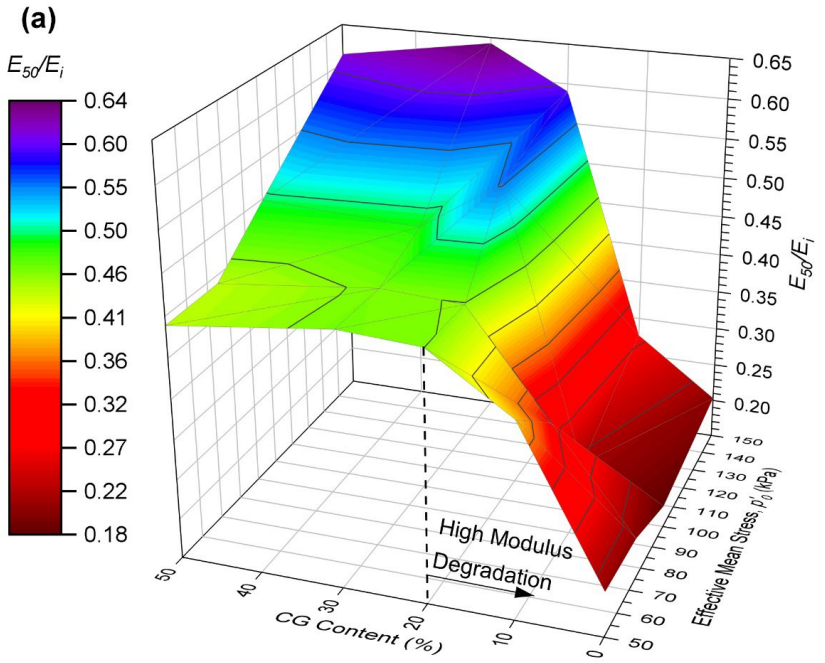
Results and Discussion

Strength and stiffness

Friction angle



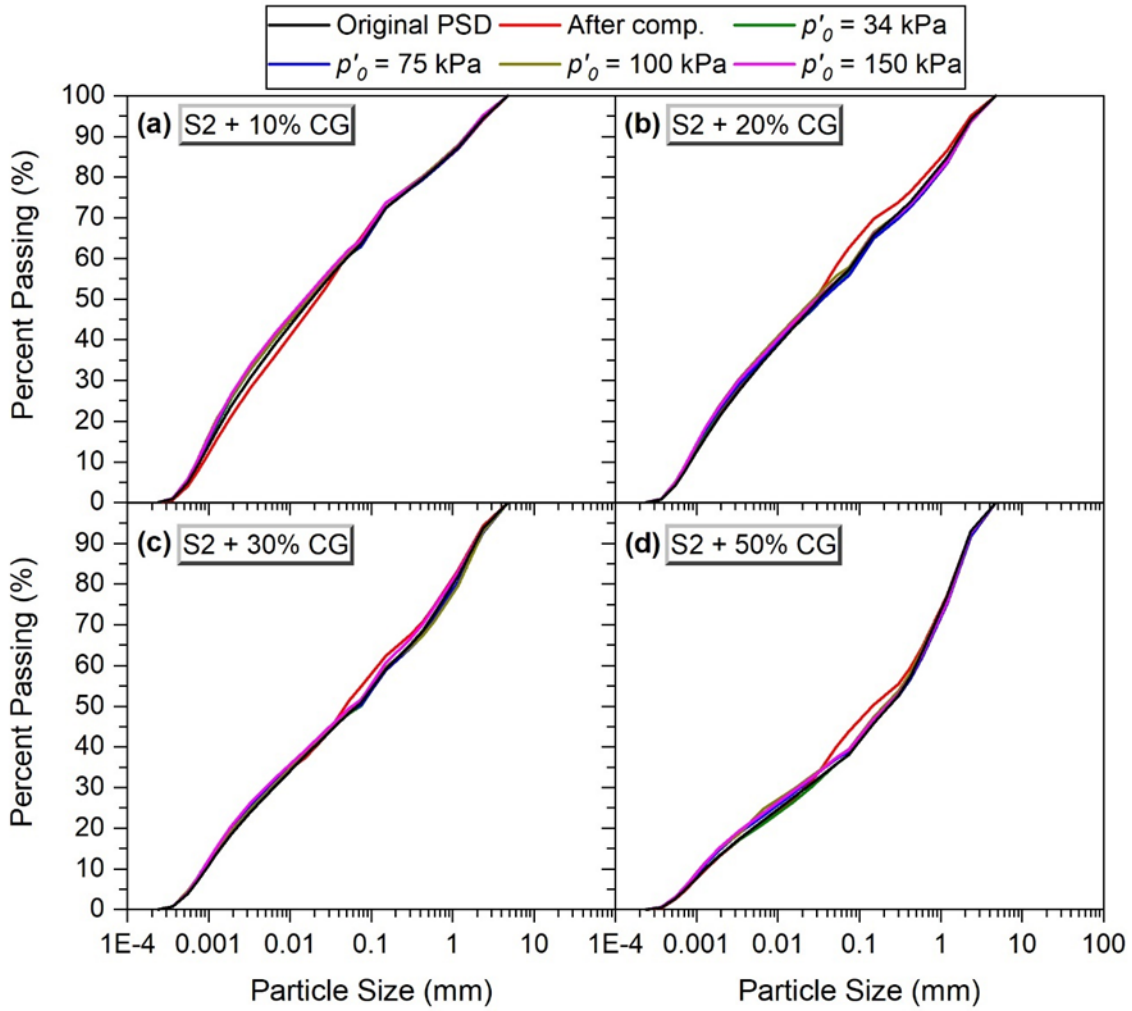
Elastic modulus degradation (E_{50}/E_i)



Incremental increase (%)	S2	S2 + 10% CG	S2 + 20% CG	S2 + 30% CG	S2 + 50% CG
φ_{cs}	-	2.8%	7.6%	3.4%	5.7%
q/p'_{cs}	-	3%	8.2%	3.6%	6.1%

Results and Discussion

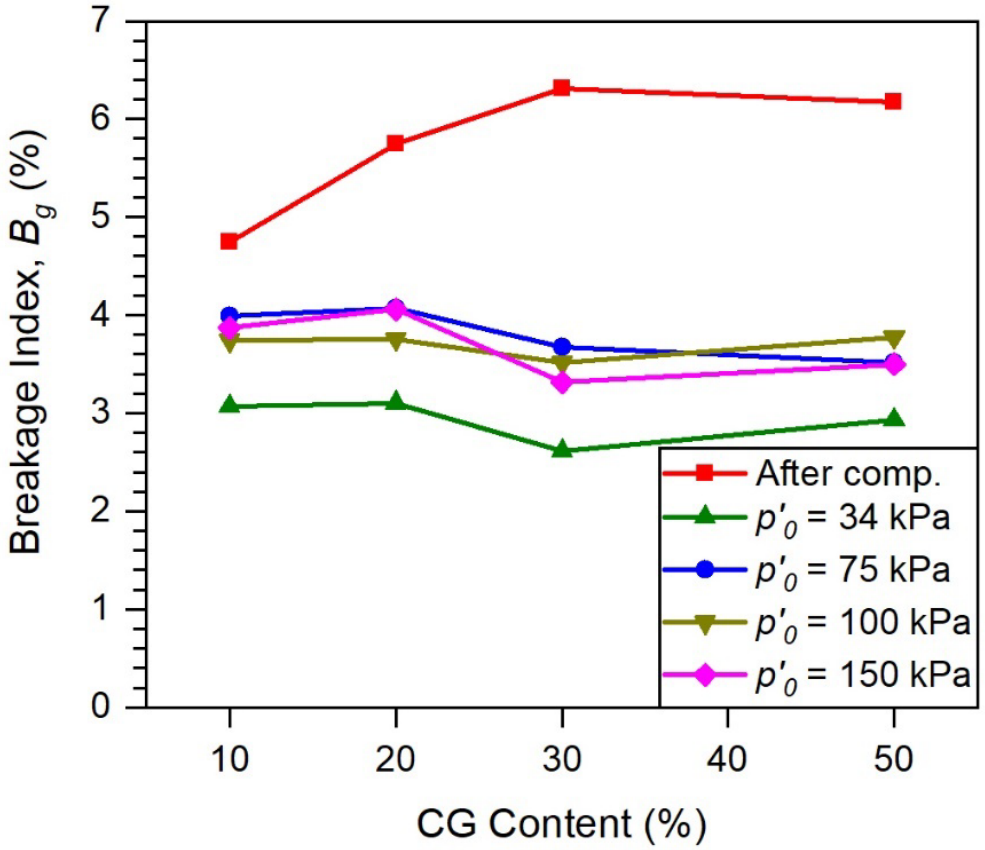
Particle breakage



Breakage Index – Marsal's Method

$Bg = \sum_1^n \Delta W_k$, if $\Delta W_k > 0$

$\Delta W_k = W_{ki} - W_{kf}$, where W_{ki} represents the percentage retained on sieve size k before the test and W_{kf} is the percentage retained on the same sieve size after the test.



Conclusion

- The addition of CG resulted in increased density and enhanced particle interlock within the soil matrix. This led to greater load-bearing capacity and reduced compressibility, thus enhancing the overall stability of the soil
- The addition of 20% CG led to an optimal soil-CG interaction which significantly increased the strength and stiffness of the soil and reduced the elastic modulus degradation
- The CG particles remained stable with minimal breakage under monotonic loading indicating the CG suitability for applications requiring robust and stable ground conditions
- In practical applications the CG-soil mixtures could be used as structural fill material for new embankments constructed for track structures.

Acknowledgments

- Supervisors: Dist. Prof. Buddhima Indraratna
  Prof. Cholachat Rujikiatkamjorn
  Dr Thanh Nguyen

- Transport Research Centre - UTS

- Industry partners (SMEC, Coffey, Sydney Trains and ARTC)


THANK YOU!