Liquefaction characteristics of sand-gravel mixtures: insights from laboratory tests

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Outline

1. Background
2. Research objectives and Planning
3. Preliminary Results
4. Conclusion

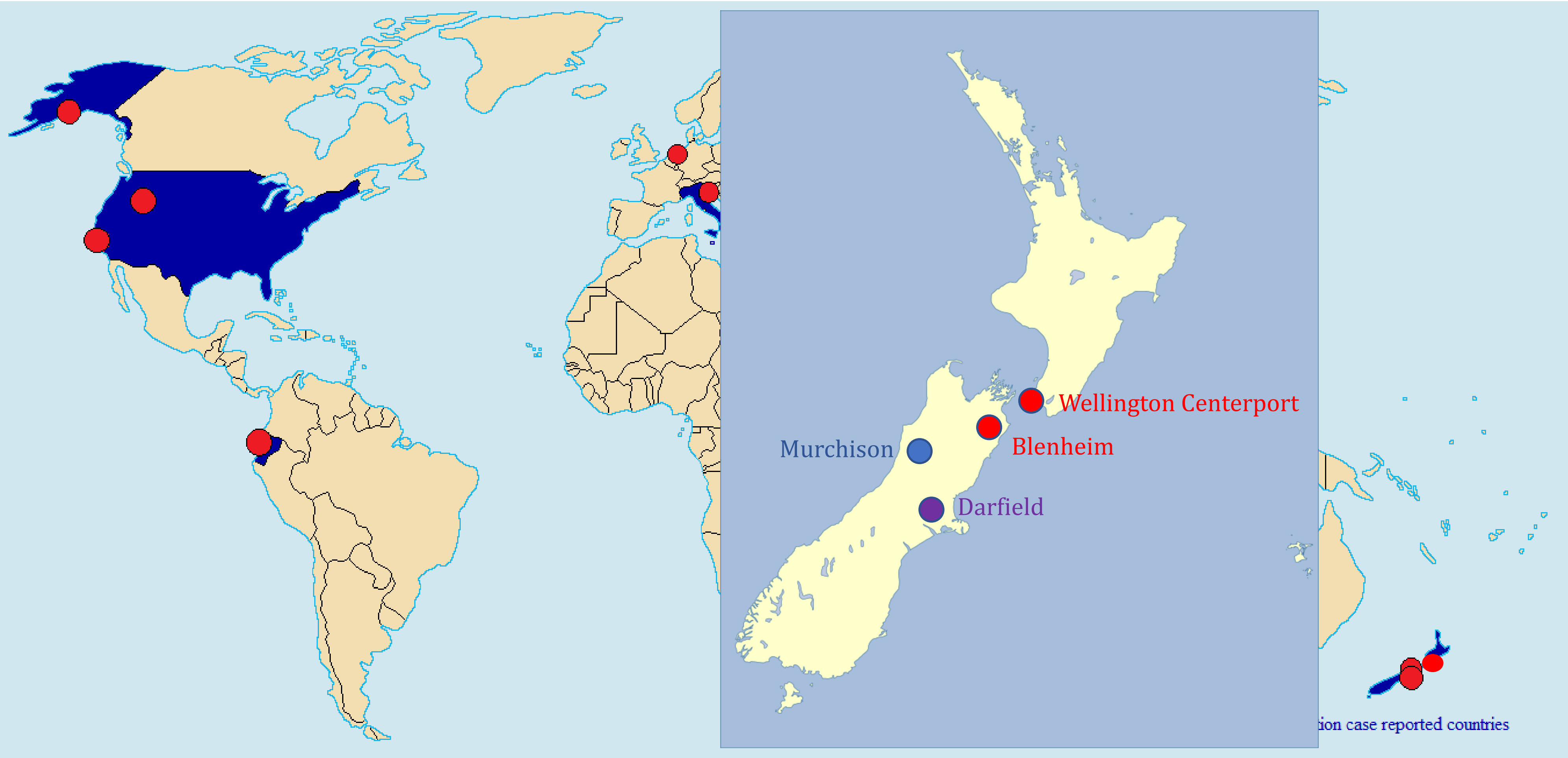
1. Background

Nigata Earthquake, 1964

Christchurch Earthquake, 2011

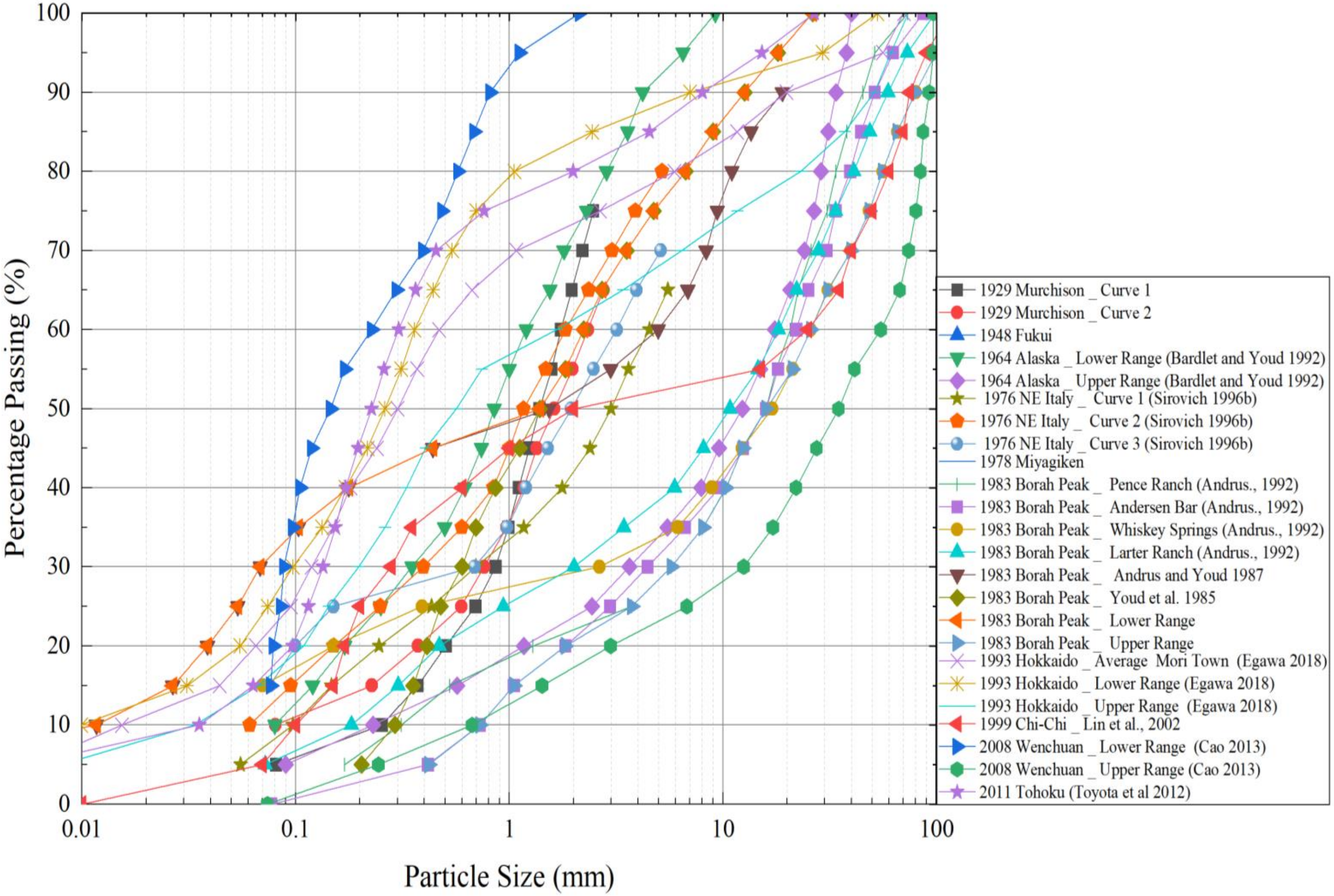
Lansdowne Park, Kaikoura Earthquake 2016

Gravelly soil liquefaction case histories



11 countries and more than 22 case histories including 3 from NZ (Murchison 1929, Darfield 2010 and Kaikoura 2016).

Gravelly soil liquefaction in natural deposits



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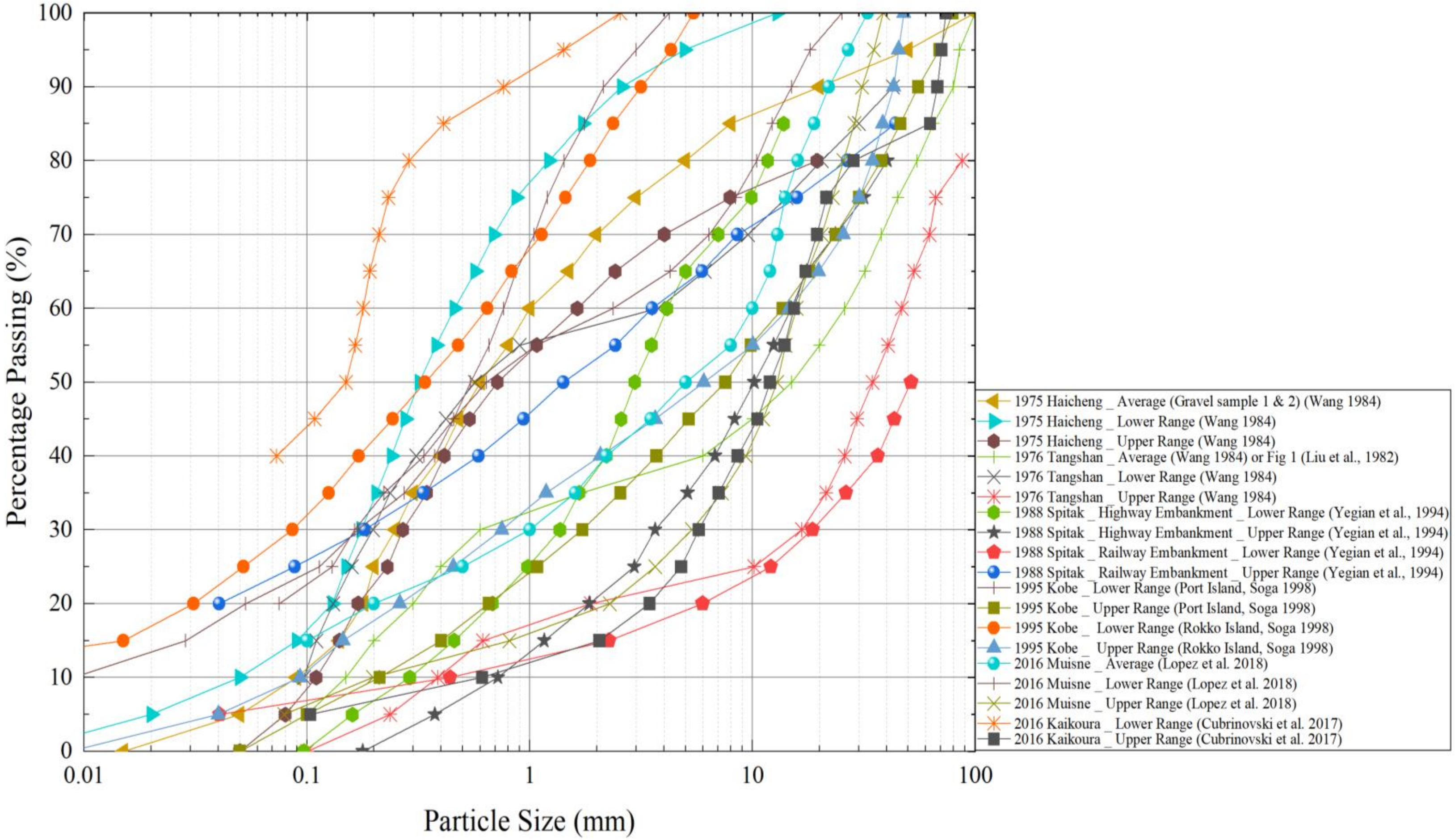
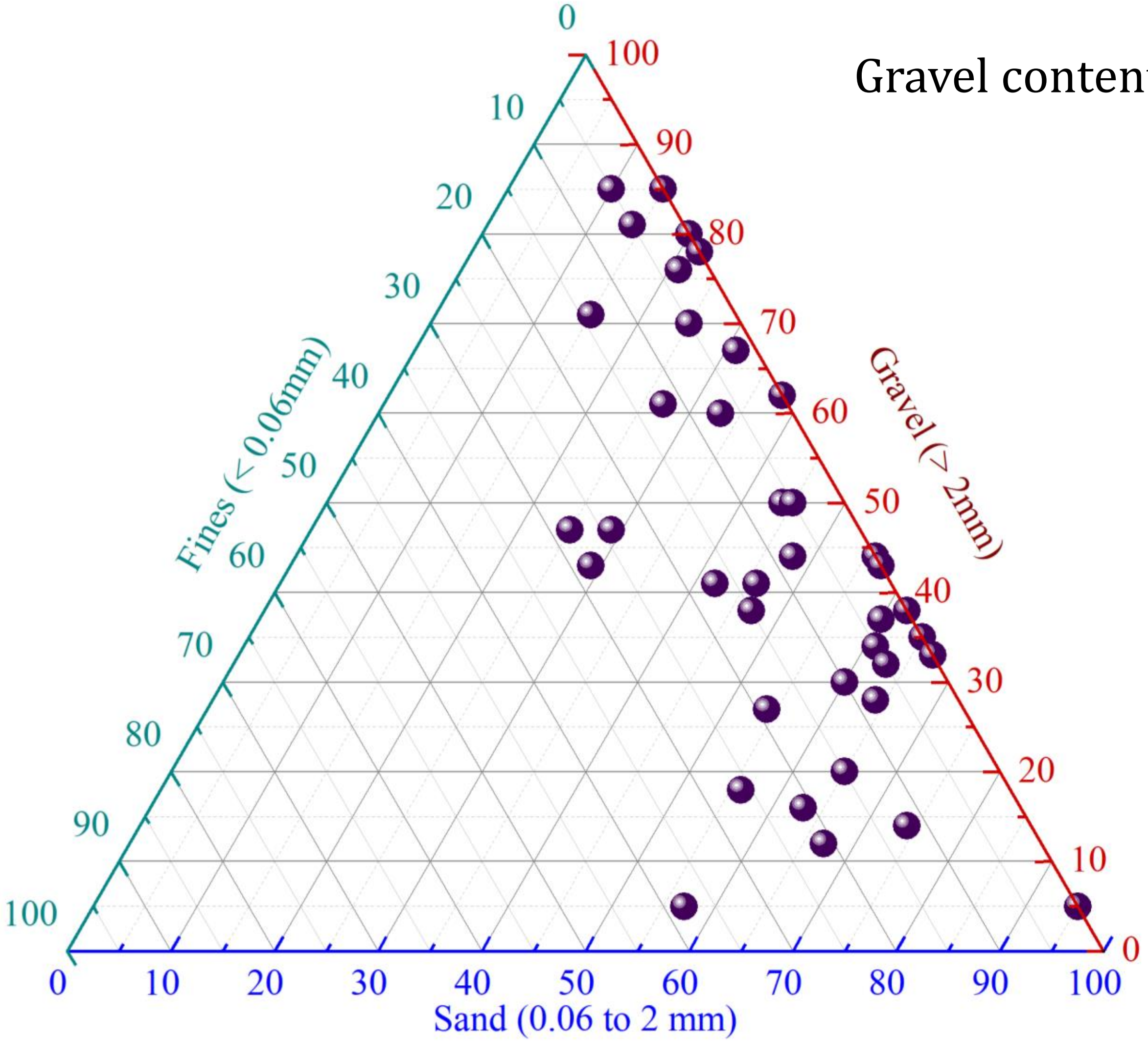
Gravelly soil liquefaction in man-made deposits



Ternary plot - liquefied gravelly soils

Gravel content ranges from 5 to 85%.



Importance of gravelly soils liquefaction study in NZ

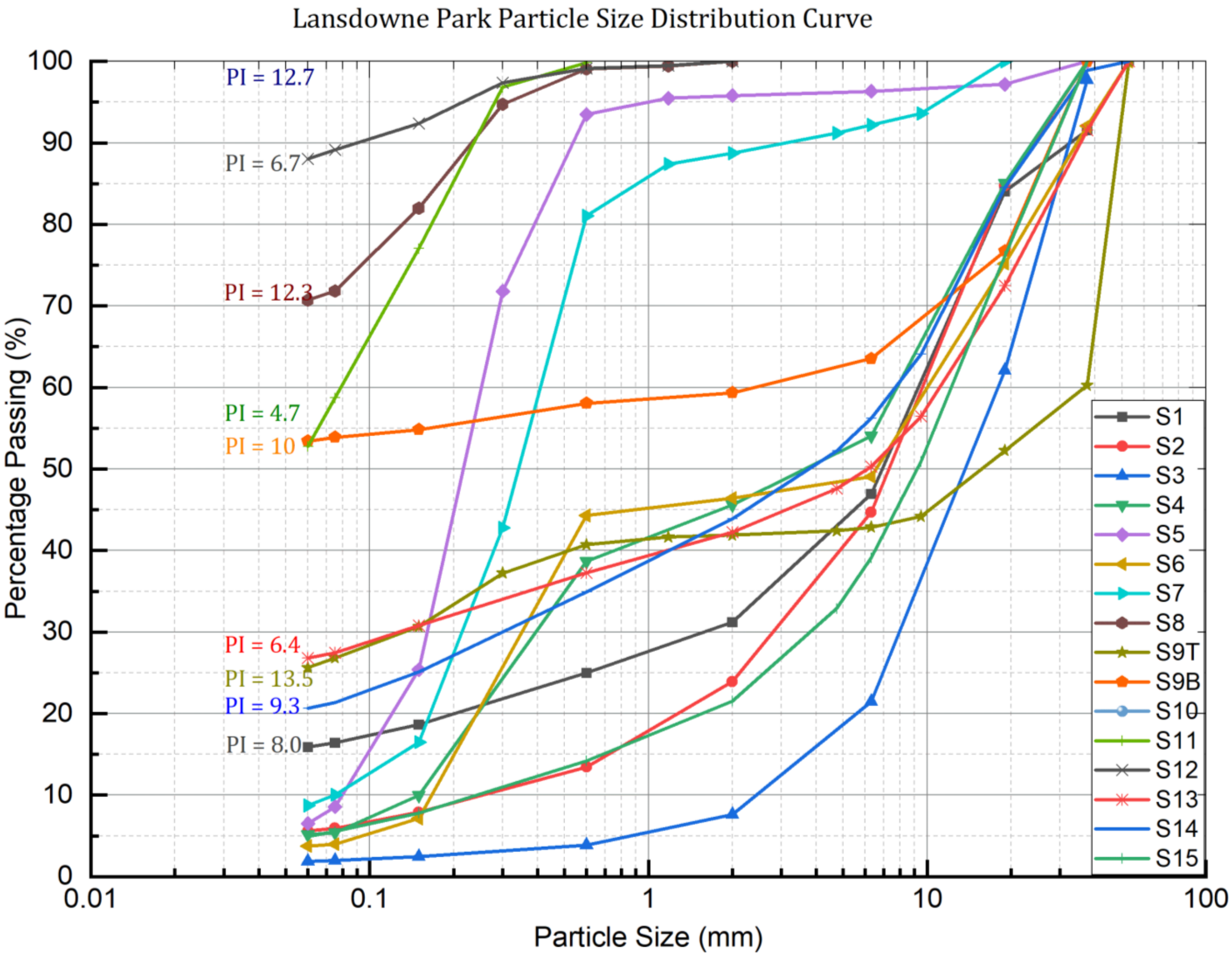
2016 Kaikoura earthquake

Gravelly soil liquefaction at Centerport, Wellington

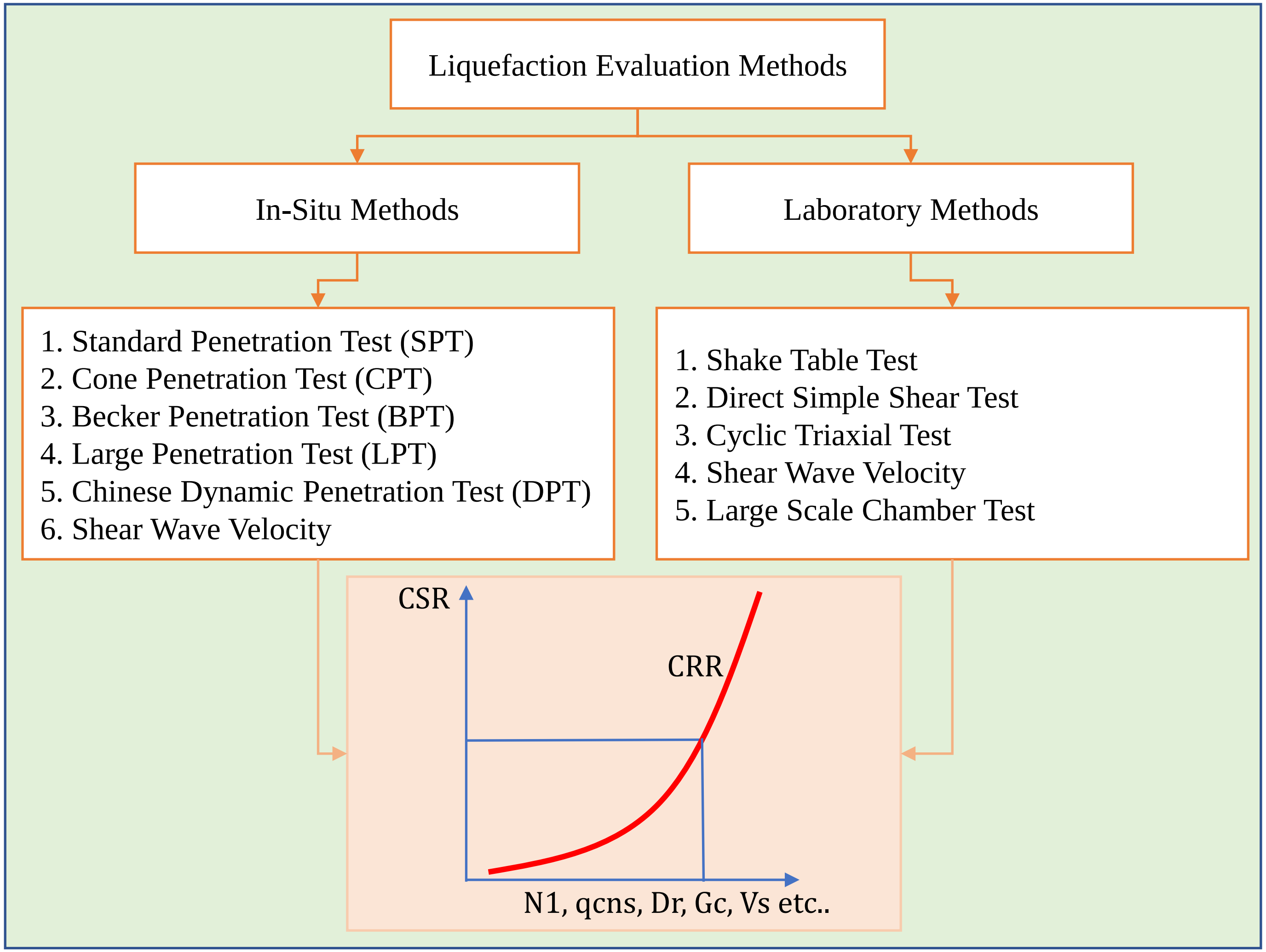
References:- Cubrinovski et al., 2017, Cubrinovski 2018

2016 Kaikoura earthquake – Blenheim (Lansdowne Park)

Chiaro et al. (2021)



Liquefaction evaluation methods



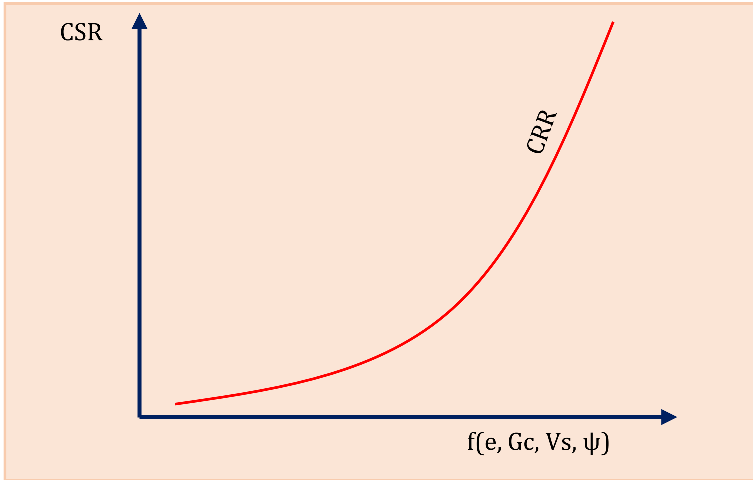
S.No.	Parameters	Effects on CSR/CRR	References
1	Fabric/ structure	Insignificant	Banarjee et al., 1979 Amini and Chakravarty 2003
2	Relative Density	Increasing	Evans and Zhou ., 1995, Toyota and Takeda 2019
3	Skeleton Void ratio	Depending on threshold sand content	Chang 2014, Chen et al., 2018
4	Gravel Content	Increasing	Lin et al., 2002, Chang 2016
5	Confining Stress	Increasing	Chen et la., 2018
6	Cu, Cc		
7	Shear Wave Velocity	Higher than sand	Andrus and Stokoe (2000), Kokusho (1995)

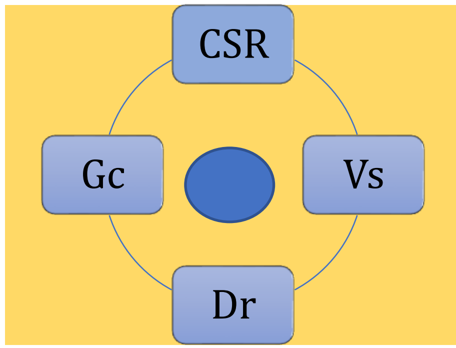
It is important to understand the combined effects of such factors and define better parameters/framework to properly describe the liquefaction potential of gravelly soils (e.g., intergranular contact index (skeleton) void ratio (e*), equivalent void ratio $(e_f)_{eq}$, state parameter (ψ), equivalent granular state parameter (ψ*)

2. Research Objectives and Planning

- To understand the combined effects of **Dr and Gc** on the liquefaction phenomena of SGMs

- To find out a suitable parameter to evaluate liquefaction resistance of SGMs
  1. Void Ratio (e)
  2. Skeleton Void Ratio (e*) or (e_{sgk})
  3. Equivalent Void Ratio $(e_f)_{eq}$
  4. State Parameter (ψ)
  5. Equivalent Granular State Parameter (ψ*)





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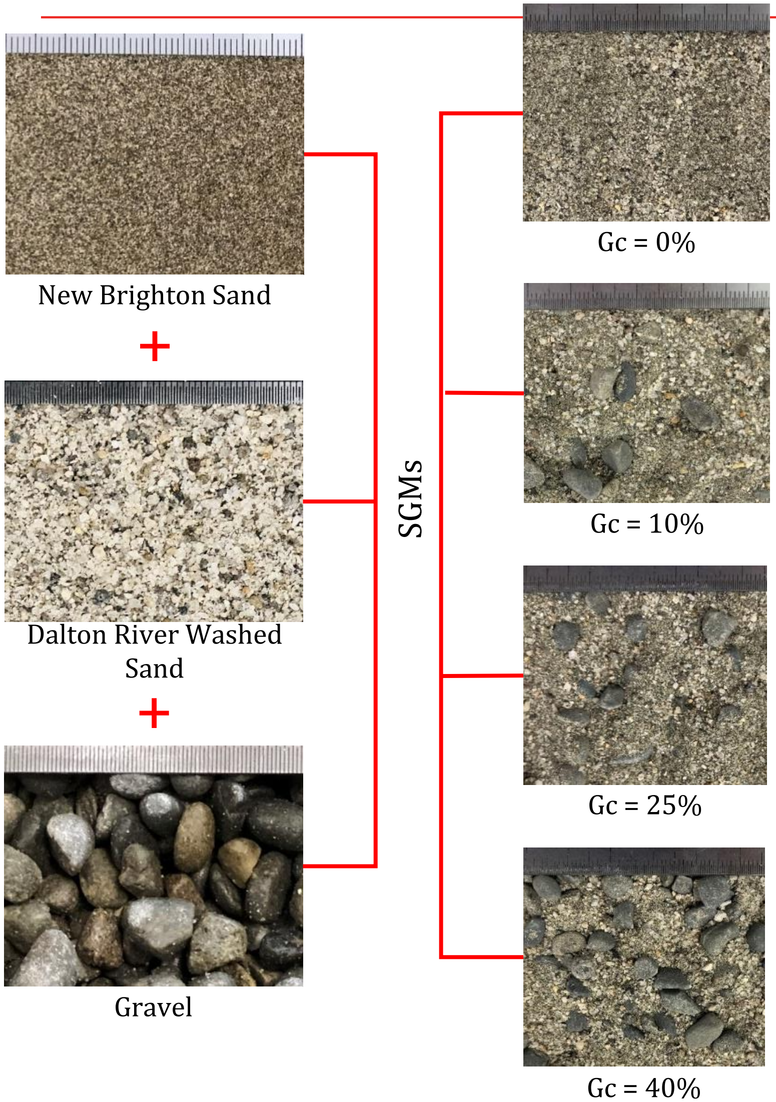
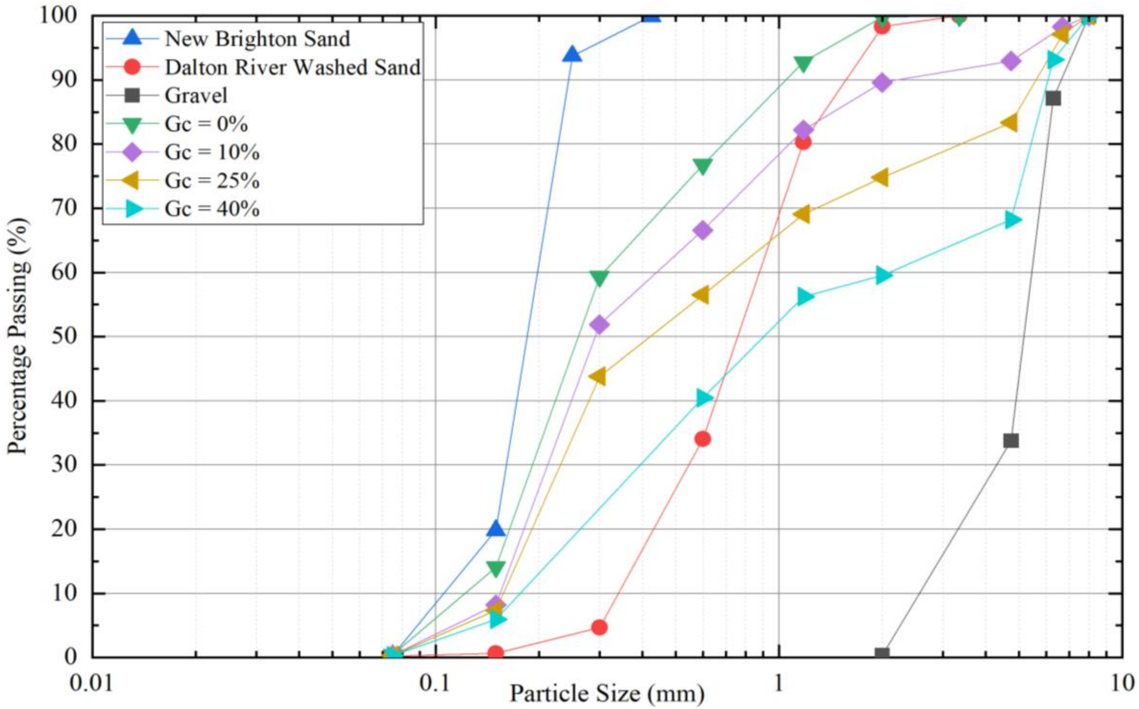
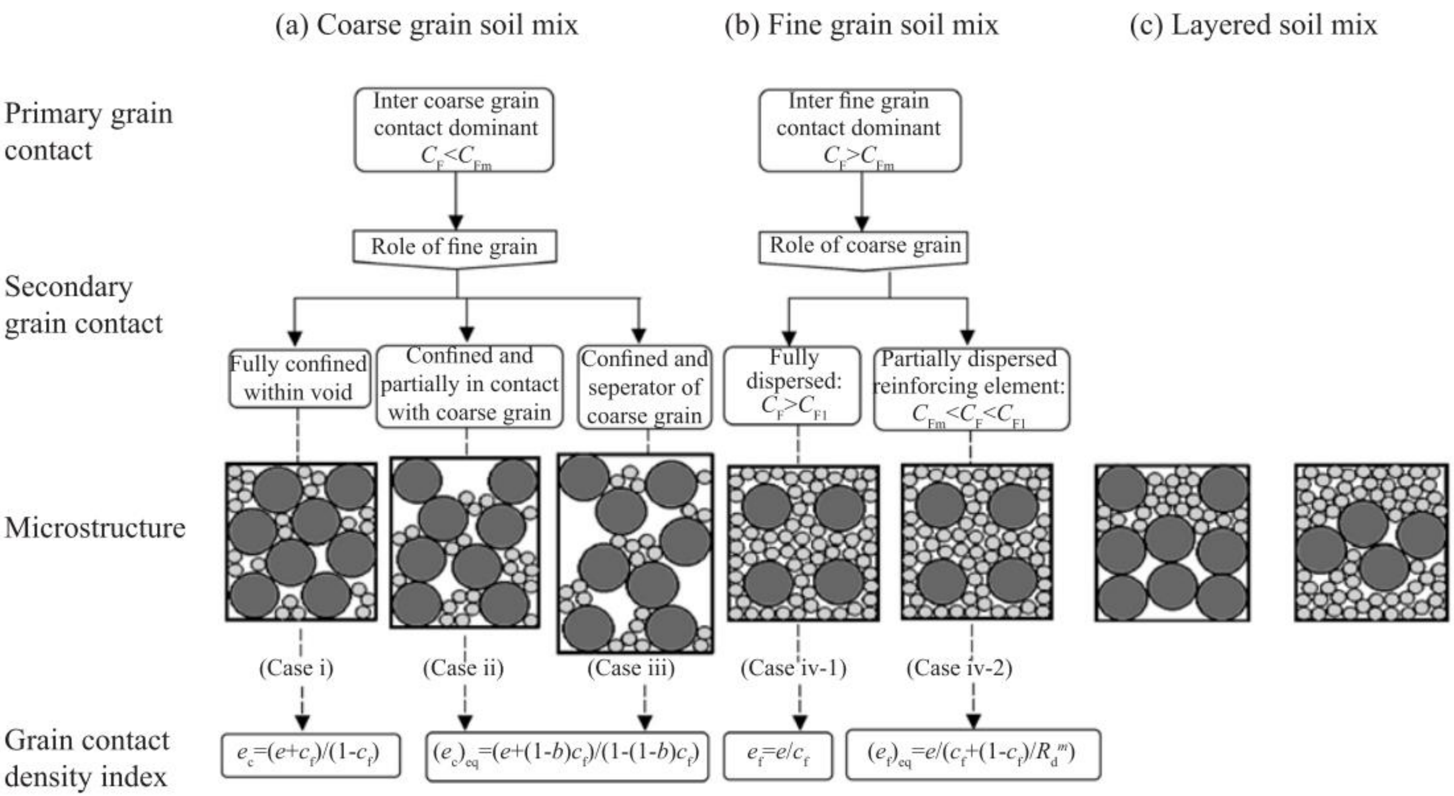
Testing materials



Materials	Max Density	Min Density	Sp. Gravity	D50
New Brighton Sand	1.66	1.34	2.67	0.19
Dalton River Washed Sand	1.55	1.27	2.64	0.75
Gravel	1.75	1.57	2.66	5



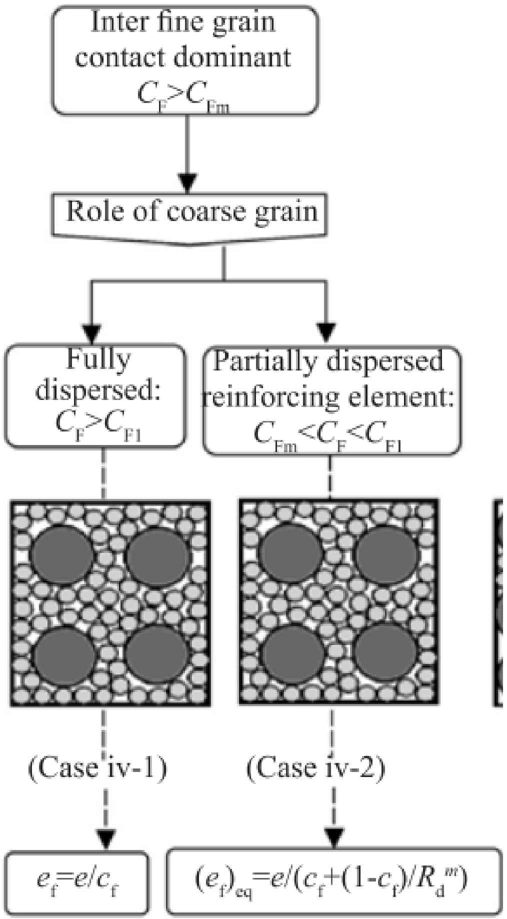
Underlaying Concept

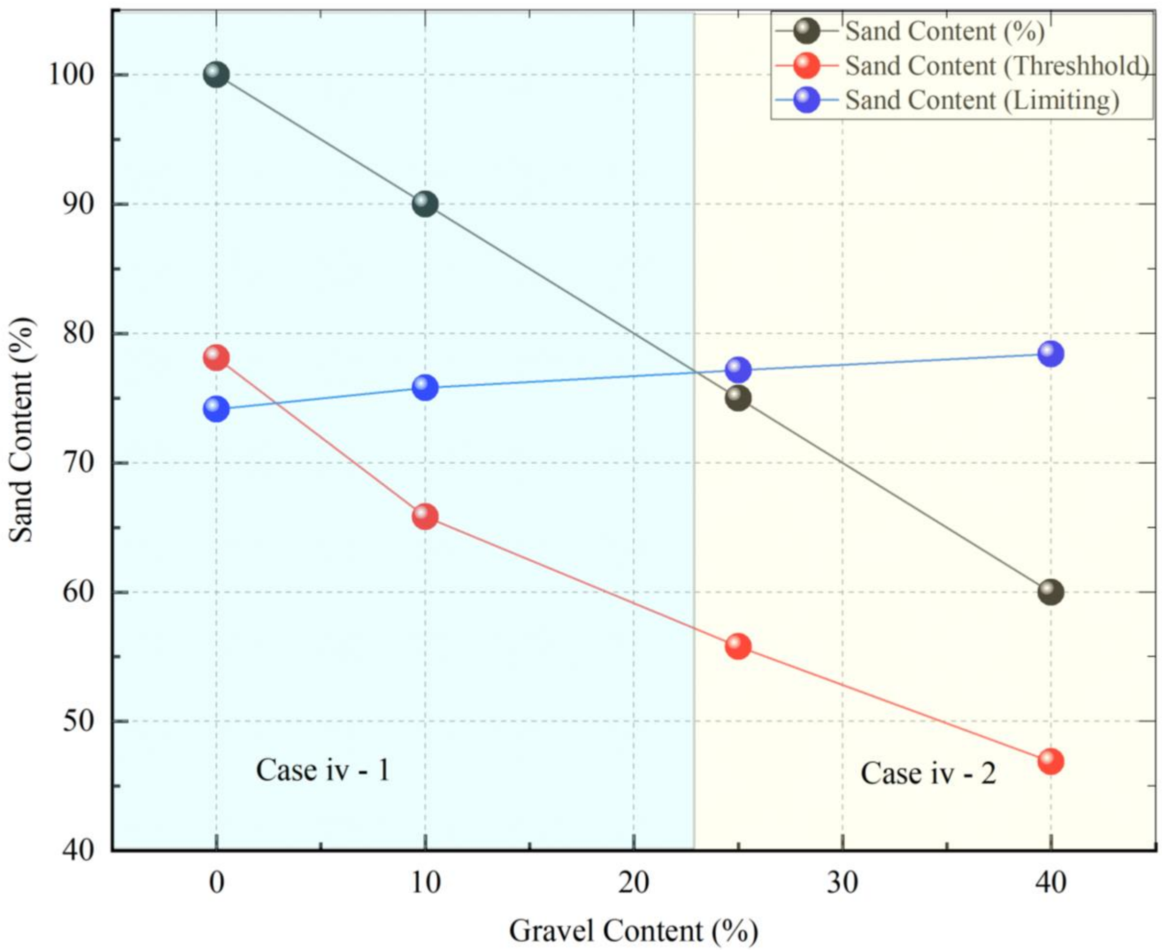


b= Portion of the fine grains that cotribute to the active intergrain contacts: e=global void ratio: C_F=fine grains content
C_{Fth}=Threshhold fine grains content, $C_{Fth}<(100e/e_{max,HF})\%$; C_{F1}=limit fines content, $C_{F1}>100(1-\pi(1+e)/(6s^3))\%>C_{Fth}$
m: Reinforcement factor; $R_d=D/d$=particle size disparity ratio; $s=1+a/R_d$, $a=10$; $e_{max,HF}$: the maximum void ratio of host fine

References:- Thevanayagam, 2007

(b) Fine grain soil mix

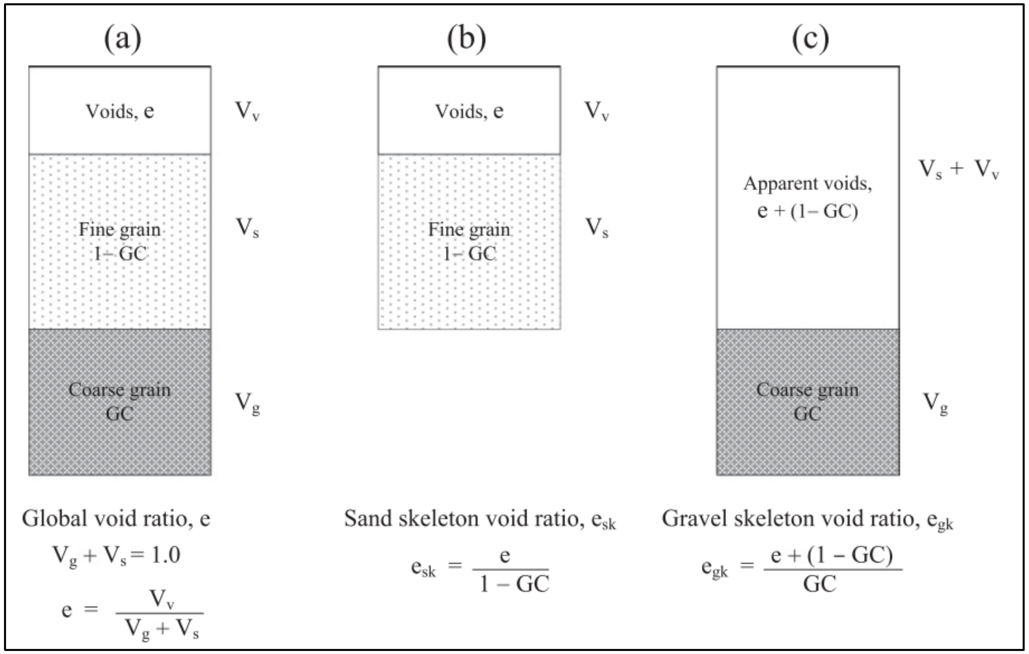




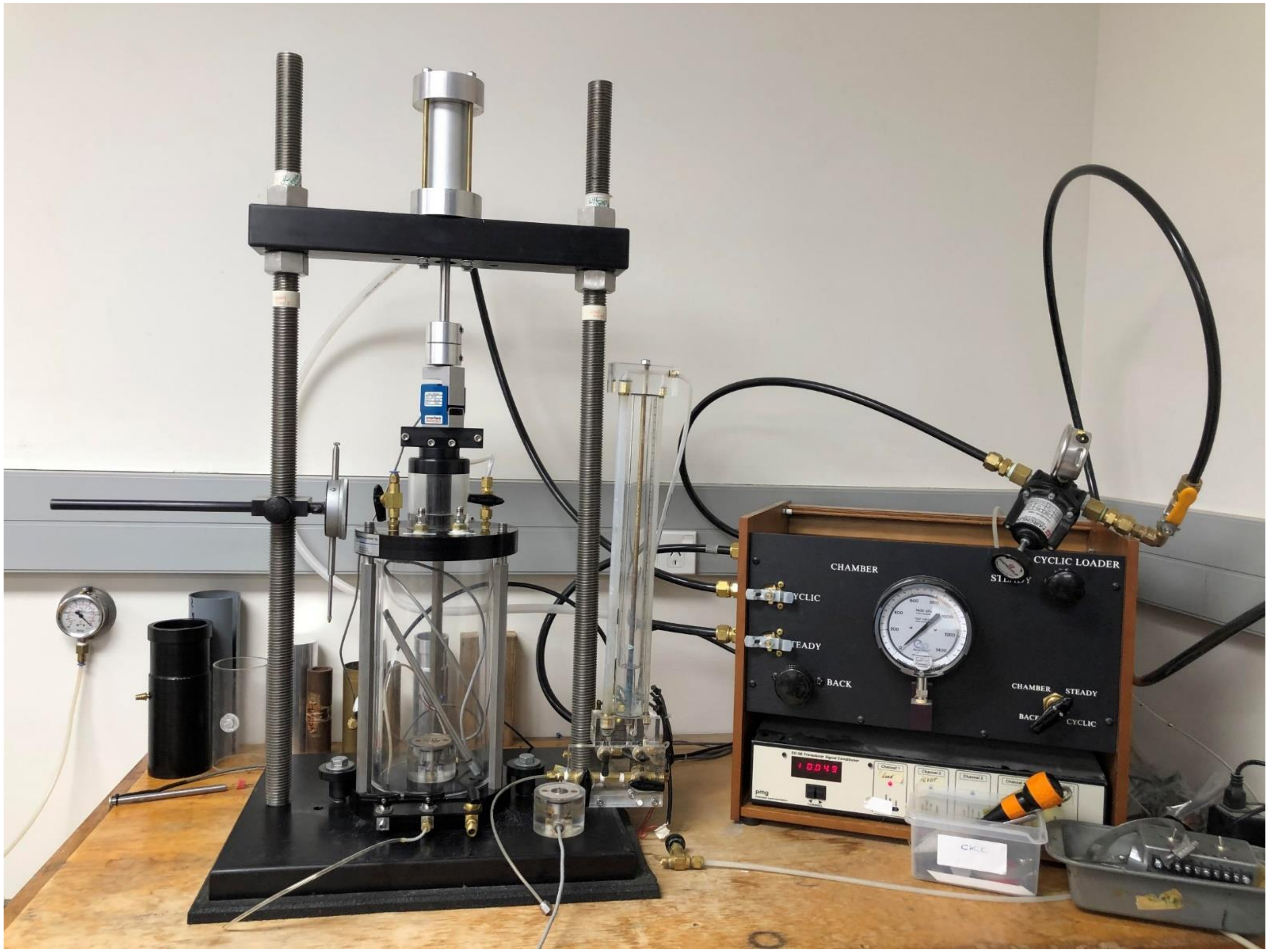
Experimental planning

Relative Density	26	46
Gravel Content	Void Ratio (e)	
0	0.8	0.73
10	0.66	0.61
25	0.57	0.53
40	0.47	0.44

Skeleton Void Ratio	0.73	0.7
Gravel Content	Relative Density (Dr)	
0	46	55
10	26	38
25	34	46
40	46	55



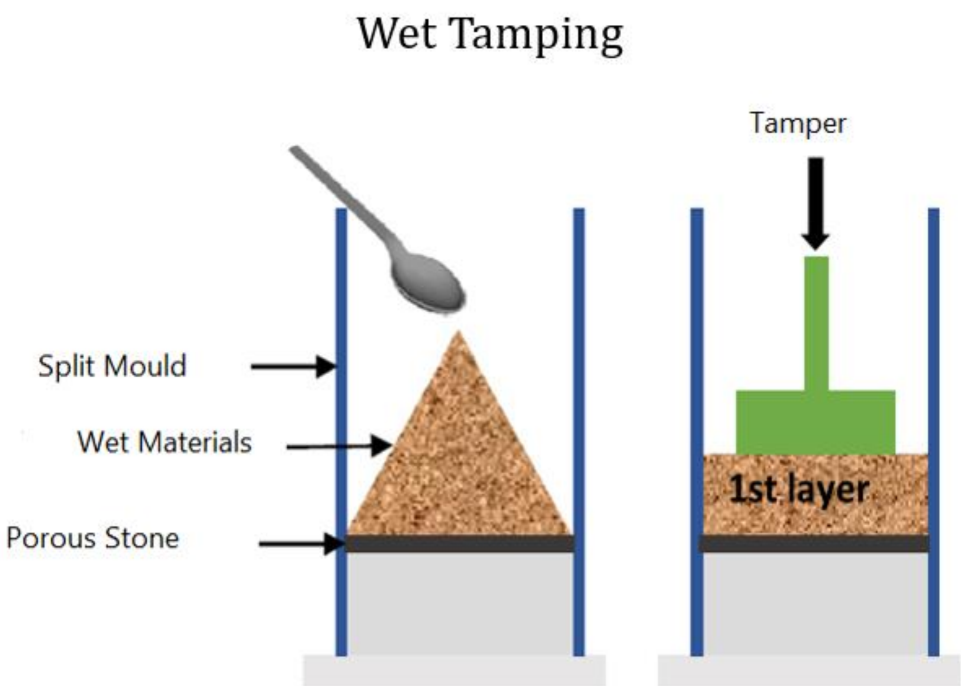
Testing apparatus



Specimen Size
61mm*130mm

Specimen Preparation Method at Laboratory

Wet Tamping, Water content = 5%
(Ishihara 1993)



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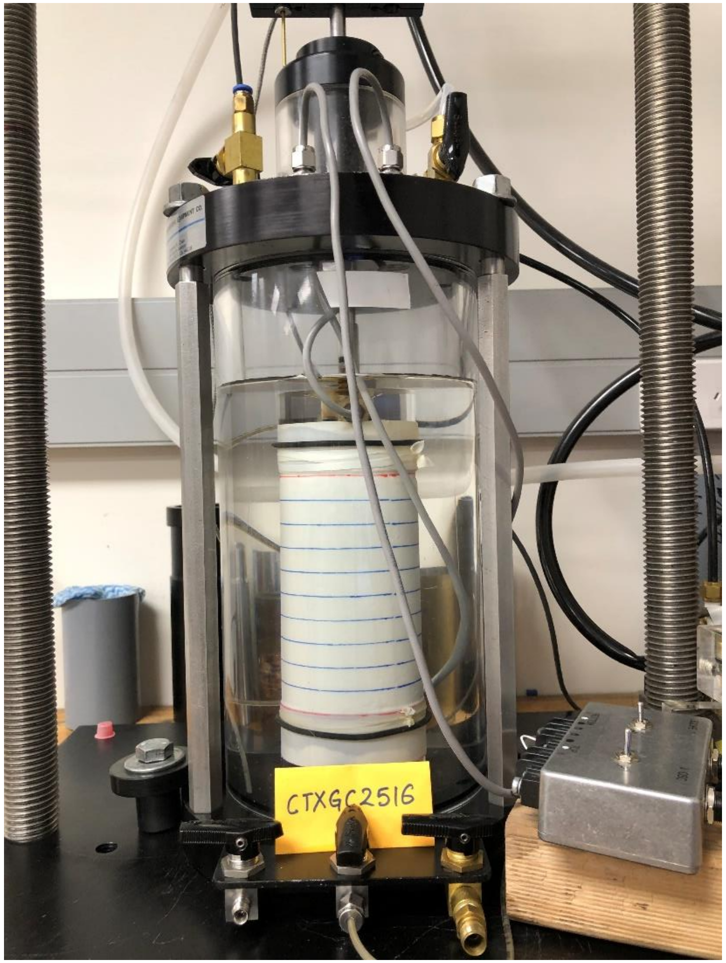
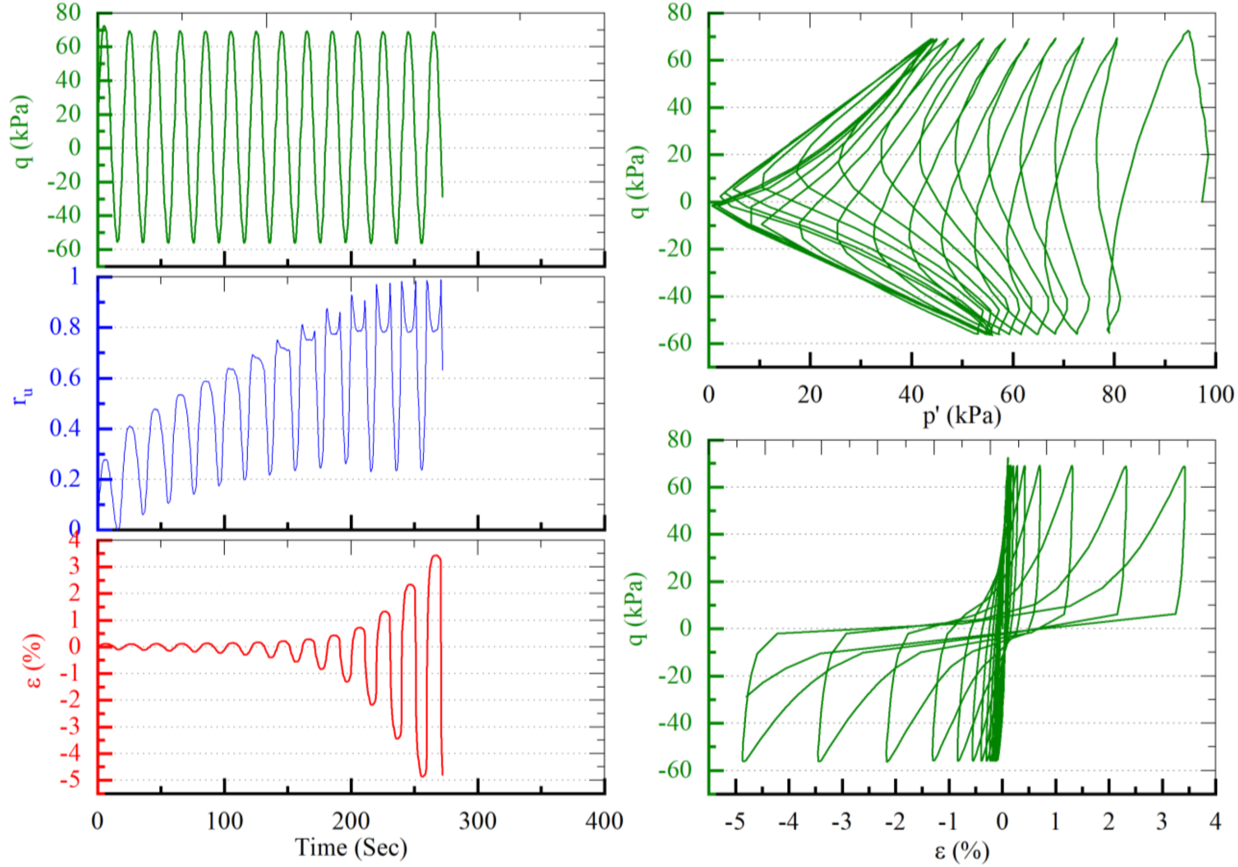
Typical Result

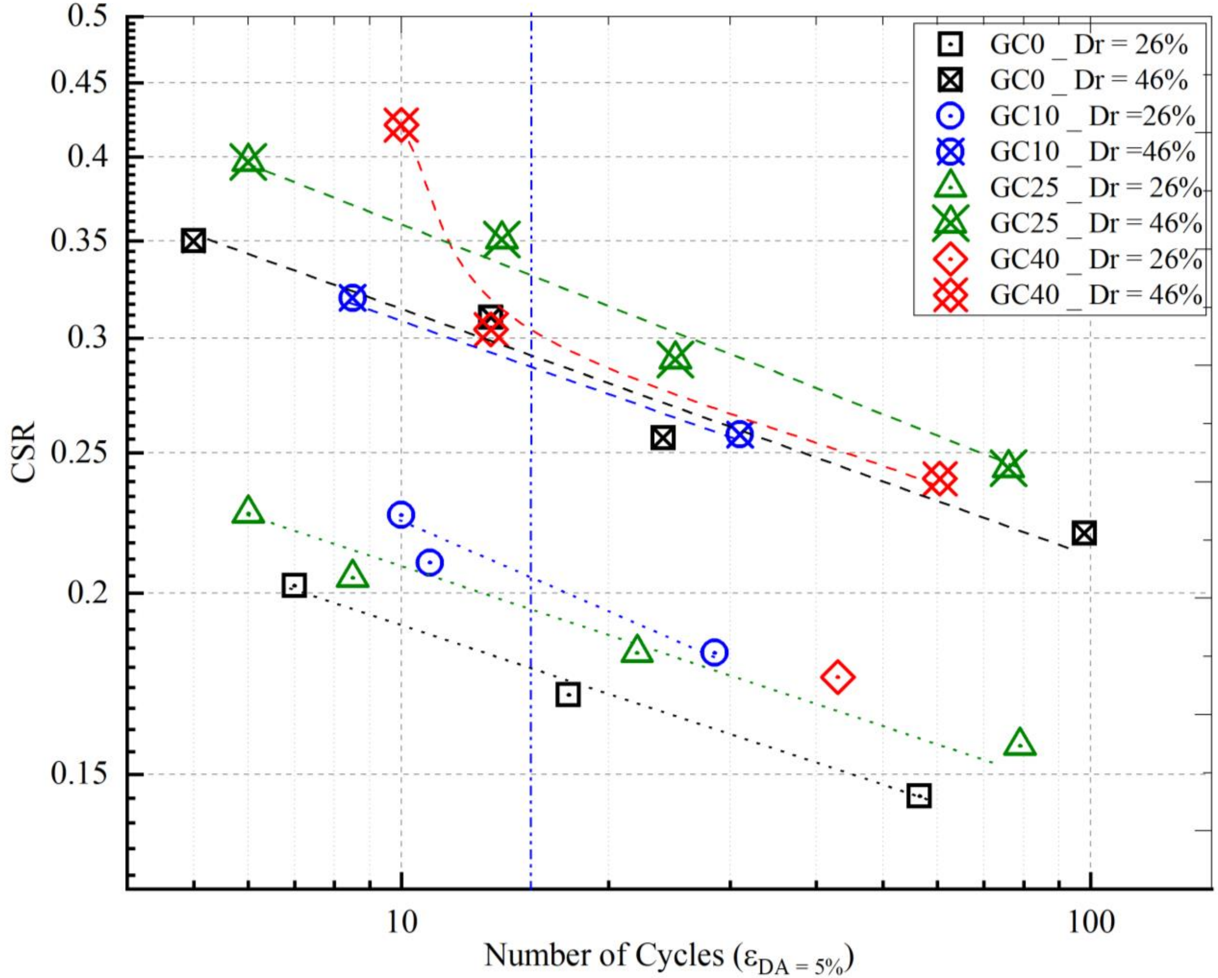


GC = 25%, Dr = 46%



Cyclic Loading Frequency = 0.05 Hz (i.e. 20 sec per cycle)

3. Preliminary Results

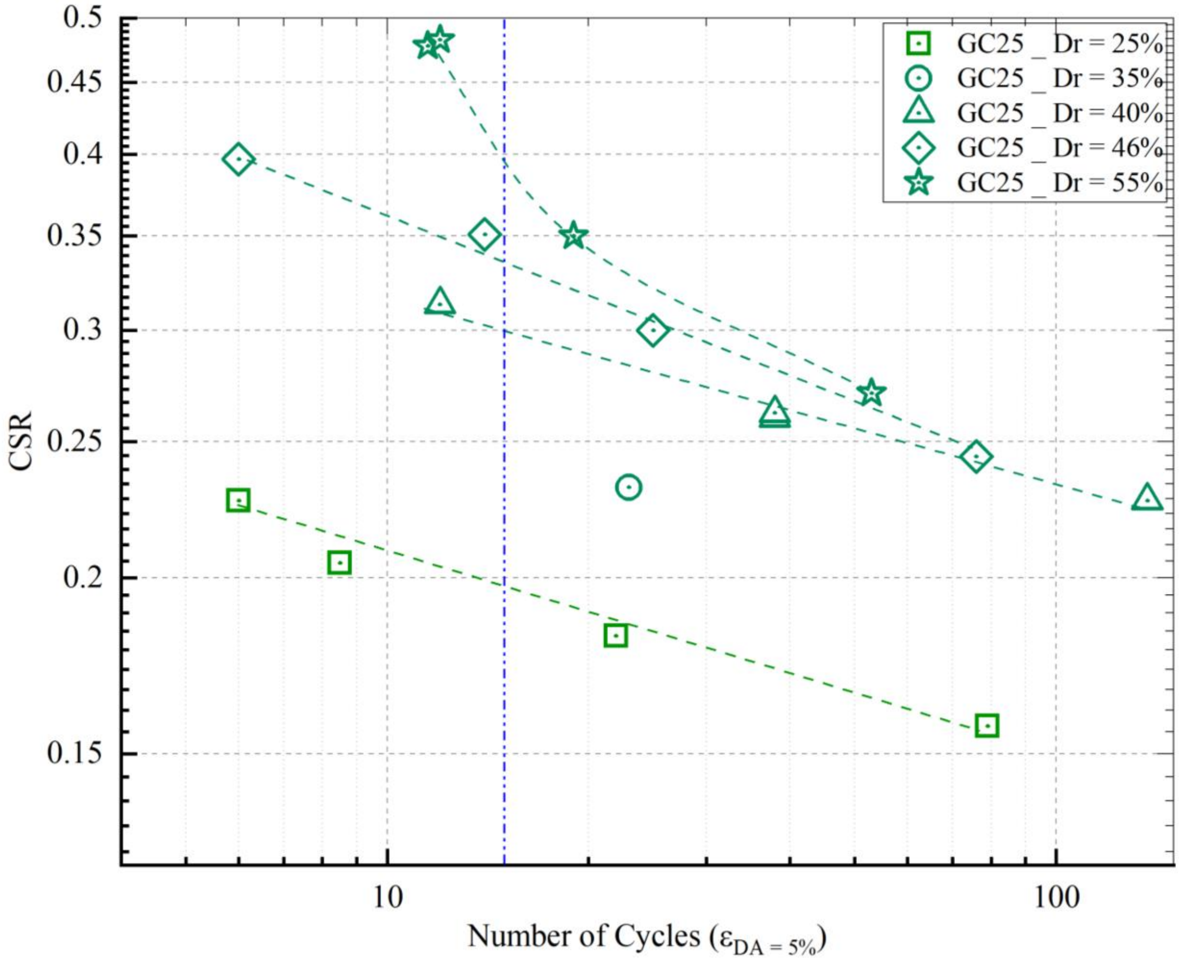


Relative Density	**26**	**46**
Gravel Content (Gc)	Void ratio	
0	0.8	0.73
10	0.66	0.61
25	0.57	0.52
40	0.47	0.44

Result

❖ No well-defined relationship between Gravel Content and CSR.

Preliminary Results

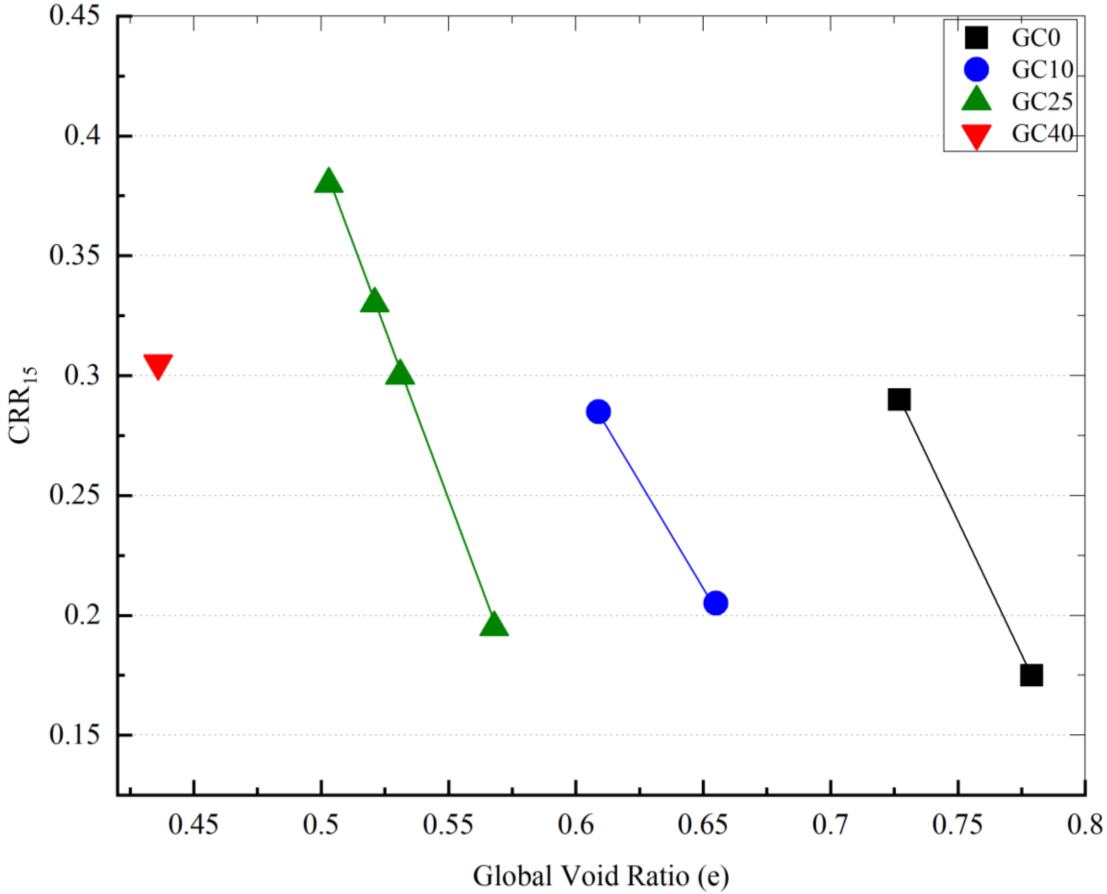


Gravel Content (Gc)	Dr	e
25	25	0.57
	35	0.54
	40	0.53
	46	0.52
	55	0.50

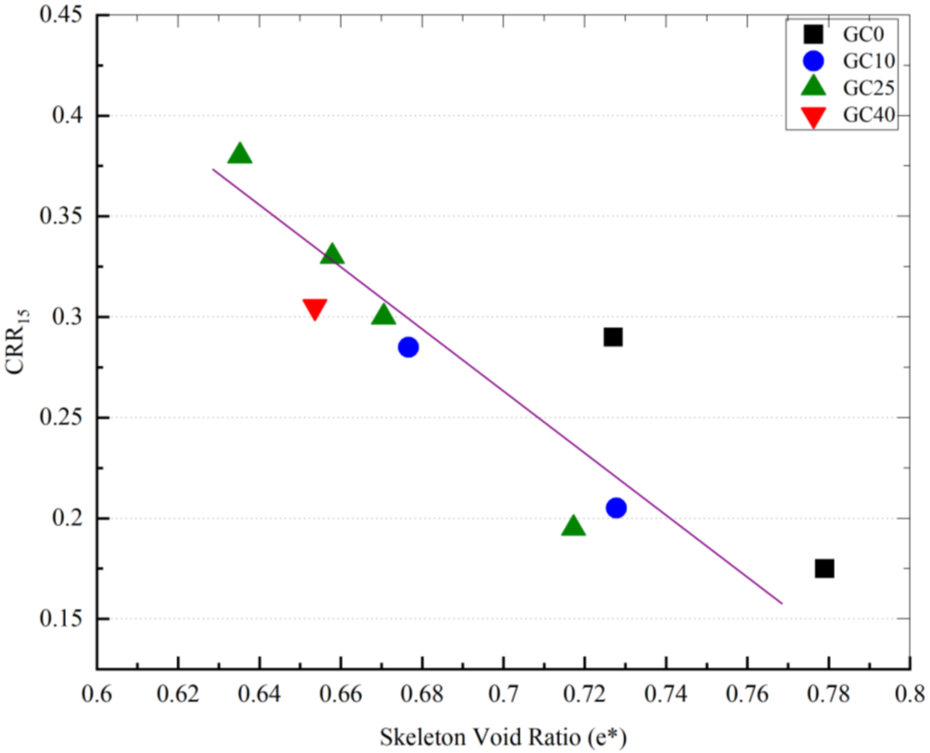
<u>Result</u>

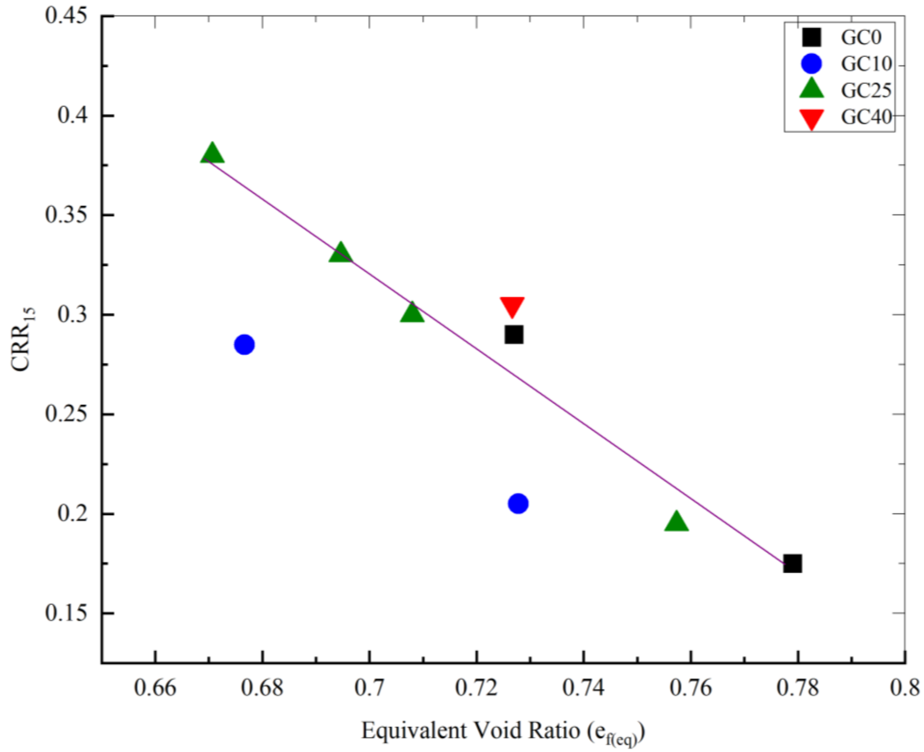
❖ CRR increases with increasing Dr

Preliminary Results :- CRR Vs Global Void Ratio

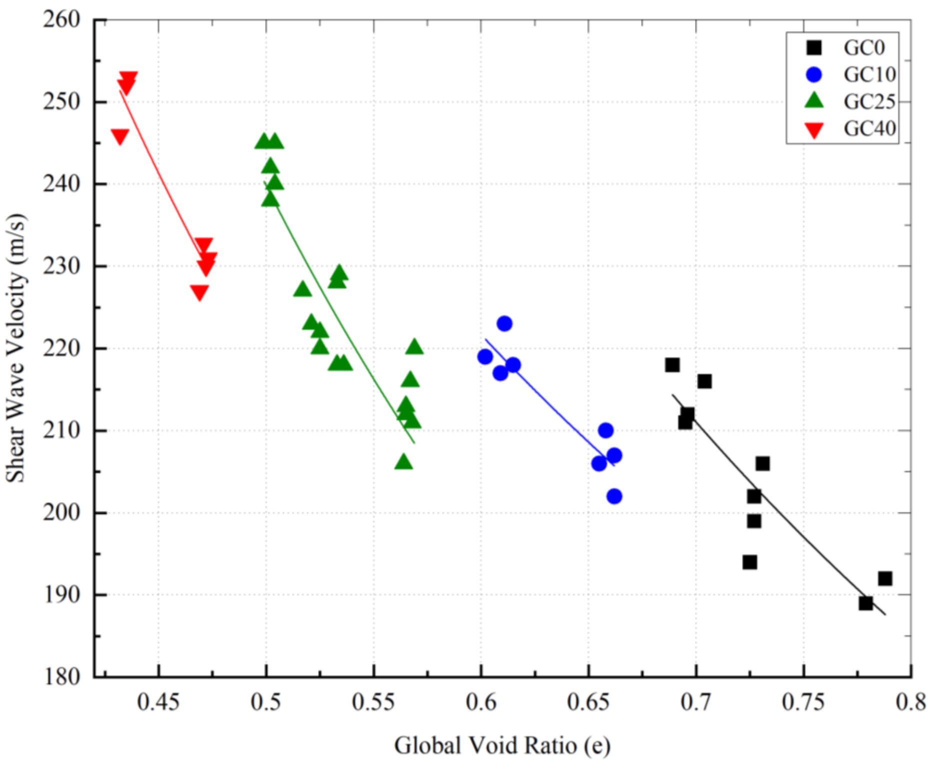


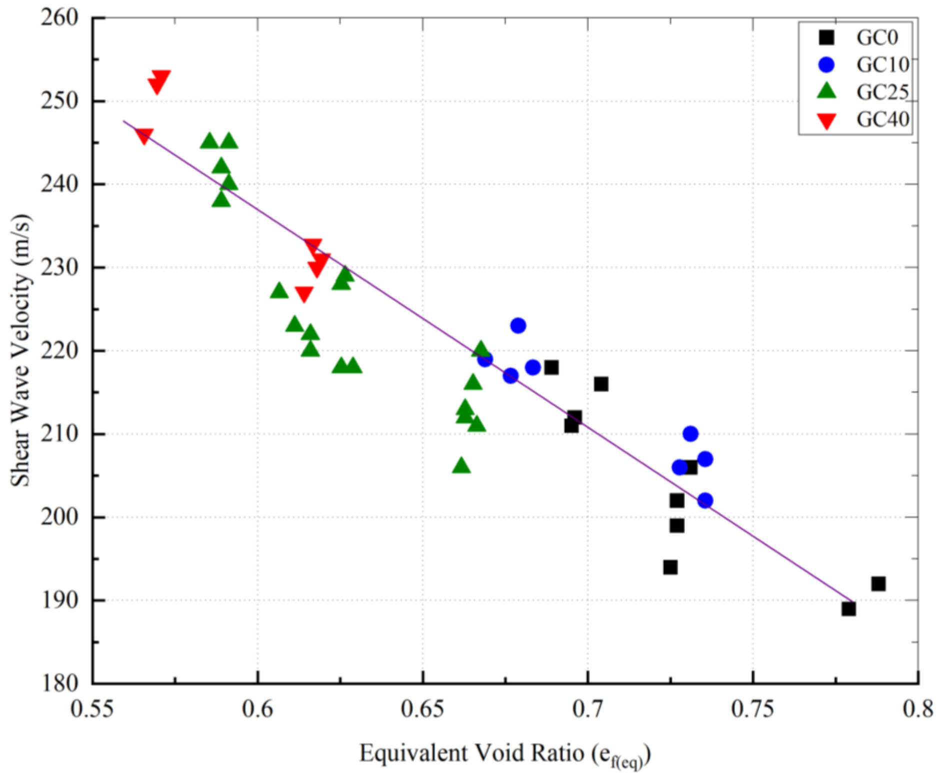
Preliminary Results :- CRR Vs Skeleton and Equivalent void ratio





Preliminary Results :- Shear Wave Velocity





4. Conclusion

- Preliminary results indicated that the **intergranular contact index (skeleton) void ratio** (e*) and the **equivalent void ratio** $\left(e_f\right)_{eq}$ are two promising parameters to describe the liquefaction potential of sand-gravel mixtures since they make it possible to combine the effects of GC and Dr

Future work

More tests will be carried out to improve the e*- CRR and $\left(e_f\right)_{eq}$- CRR relationships, and verify if this approach is suitable also for SGMs prepared with different preparation methods (i.e., will these relationships be unique for different soil fabric/structures?)

Acknowledgements

Supervisory Team

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Thank you

Questions and Suggestions will be greatly appreciated.