Analysis of Effectiveness of Geotextile in Encasing Stone Columns for Embankment over Very Soft Soil in Coastal Areas

Pham Van Hung[1,2]

[1)] Department of Infrastructure Engineering, Faculty of Civil Engineering (HUMG)
[2)] Geotechnical Engineering, Construction Materials and Sustainability – GCMS, Hanoi University of Mining and Geology

March 2023

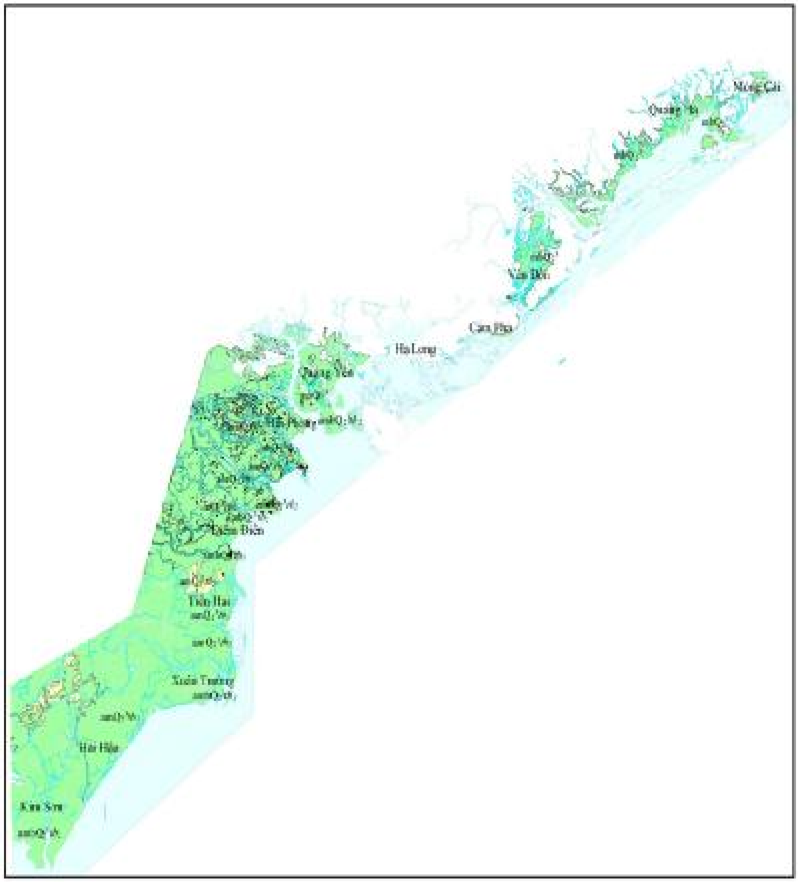
OUTLINE

I. Introduction

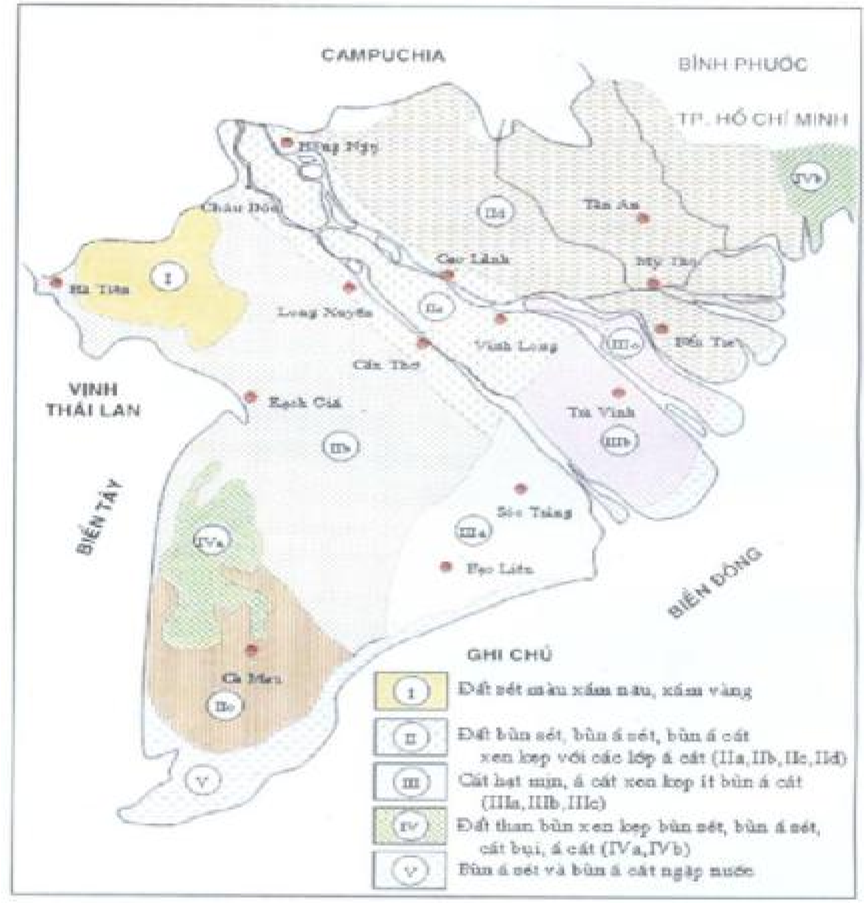
II. Technology and mechanism of geotextile encased stone columns reinforced soils

III. Analyses of the effectiveness of geotextile encased stone columns for embankment over very soft soil in coastal areas

Geological conditions of Coastal area in Vietnam



Characteristics of soft soil distribution in the Northern coastal area [1]



Characteristics of soft soil distribution in the MeKong delta [2]

[1]. Ta Duc Thinh et al, 2021. Soft soil and treatment technology
[2]. Đỗ Minh Toàn (Chủ biên), 2009. “Nghiên cứu đặc tính xây dựng của trầm tích loại sét amQ22-3 phân bố ở đồng bằng Cửu Long phục vụ gia cố đất nền bằng phương pháp làm chặt, có sử dụng các chất kết dính vô cơ”.

Geological conditions of Coastal area in Vietnam

Characteristics of soft ground structure in coastal area:

- Almost soft soil layers close to the surface.
- Variety in depth and thickness of soft soil layer, 5 to 30 m
- Variety in soft soil types: peat, silt, organic, soft clay, loose sand…
- High level of underground water.

Building the constructions on coastal areas faces the difficulties and challenges

Soft soil improvement/reinforcement methods

- Partly and fully soft soil replacement
- Soil compaction
- Prefabricated Vertical Drain combined Vacumm and Preloading
- Piles: bamboo, rigid inclusions, soil-cement, sand-cement columns,…
- Granular columns: sand, stone, …
- Geosynthetics: geotextile, geogrid and geocell
- Combination of some methods
- ….

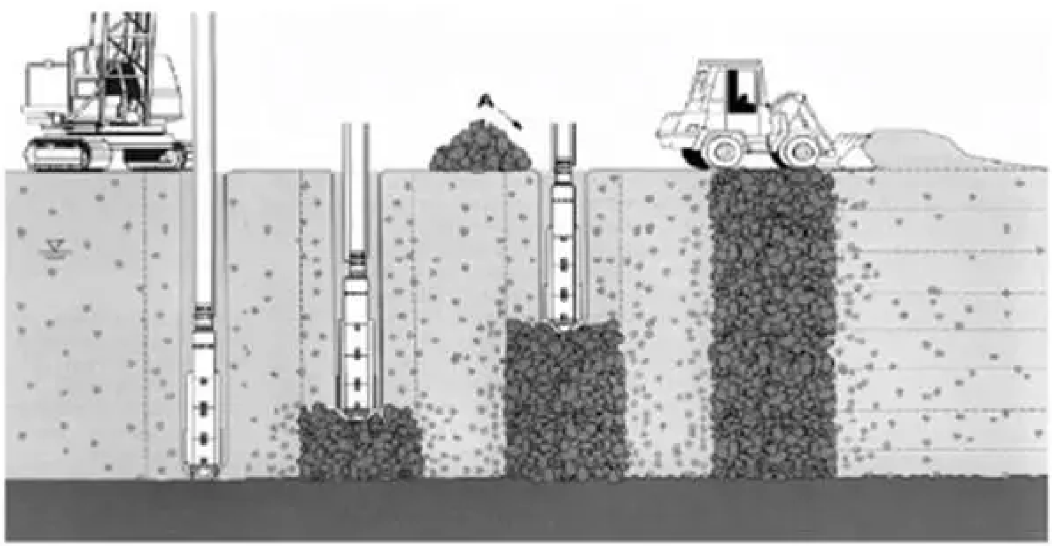
The selection, usage of these above methods depends on geological condition, machine supply, and construction type.

Soft soil reinforcement using stone colums

Stone columns, also known as granular piles, consist of stone aggregates compacted into a vertical hole.

This method of ground improvement is also called **vibro replacement**

used in Europe since the 1950s, and in the United States since the 1970s



Advantages

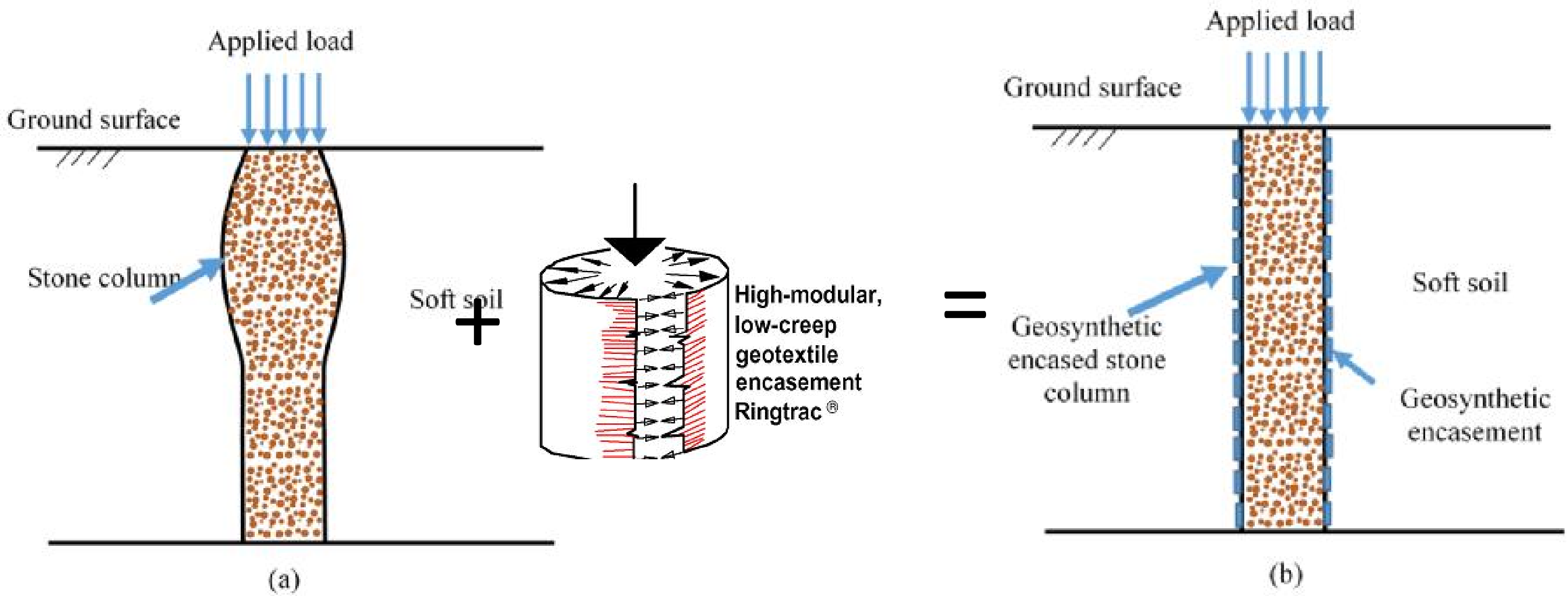
- A decrease in total and differential settlements
- Be suitable for deep soft soil
- An increase in consolidation settlement.
- Simple method

Disadvantages:

- Large radical displacement
- Not be a good choice when soil is sheared and slided
- The pervasion of soil in skeleton soil particles
- c_u and s_u more than 15 kN/m^2

Soft soil reinforcement using encased stone columns

A combination of stone columns and geotextile = geotextile encased stone columns (GEC)



Stone column

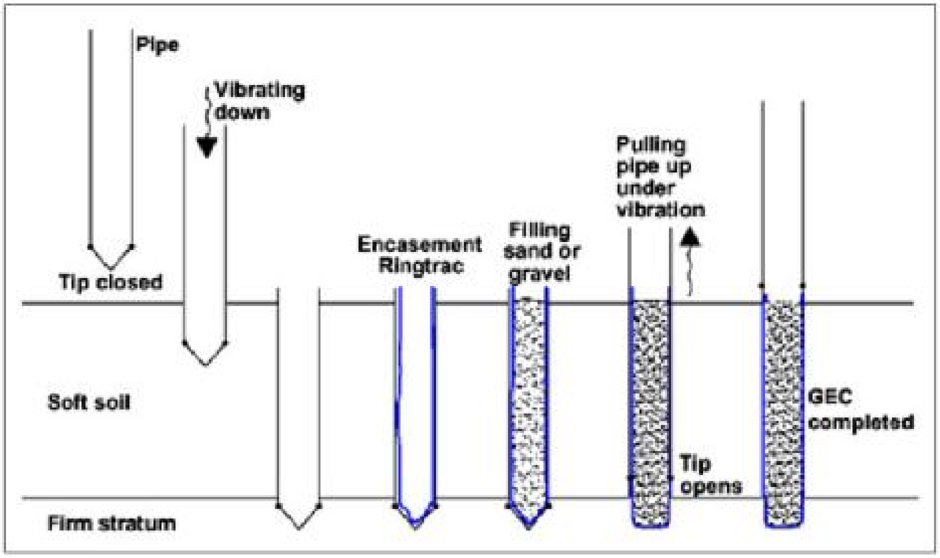
Geotextile encased stone column

Encased stone columns is more effective than stone columns for reinforcing the extremely soft soil with c_u hay s_u less than 15 kN/m^2 [3]

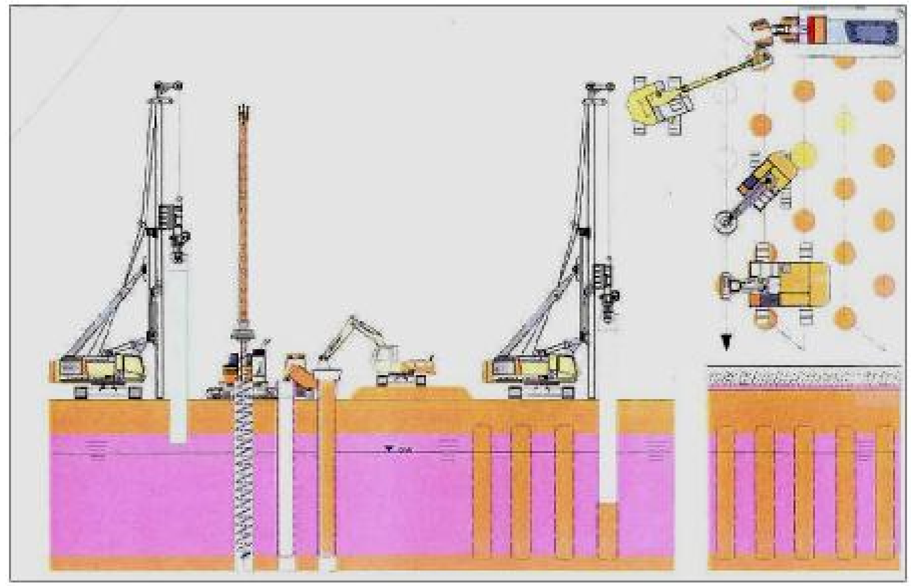
[3] Van Impe, W. and Silence, P., Improving of the Bearing Capacity of Weak Hydraulic Fills by Means of Geotextiles. Proceedings of the 3rd International Conference on Geotextiles, Austria: Vienna:1411-1416, 1986.

Construction technology

Method of pressing combining vibration



Drilling method



As compared to stone column method, the GEC is more suitable for extremely soft soil, the embankment on high water level, high bearing capacity.

Construction sequences

1. Drilling hole

2. a screw thread in geotextile, stone pour

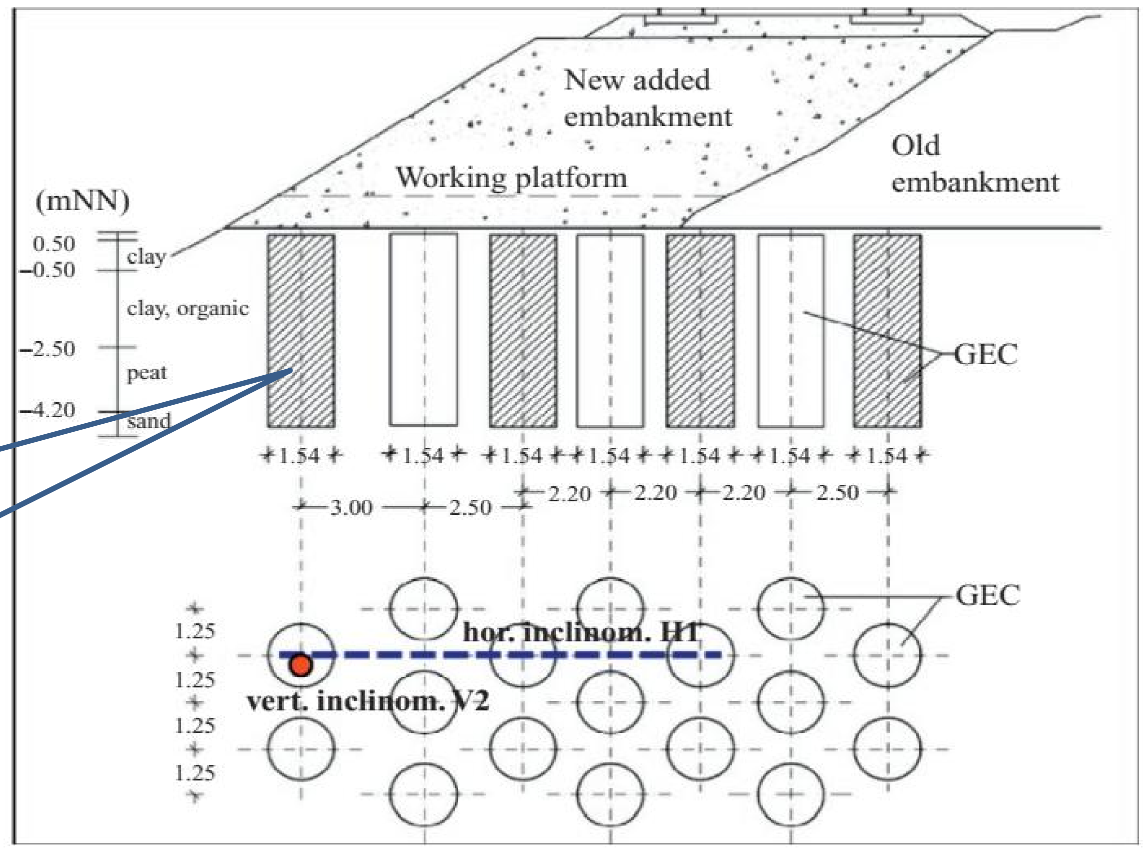
3. Granular embankment

Application of Encased stone columns

Widening railroad at Waltershof (1995)

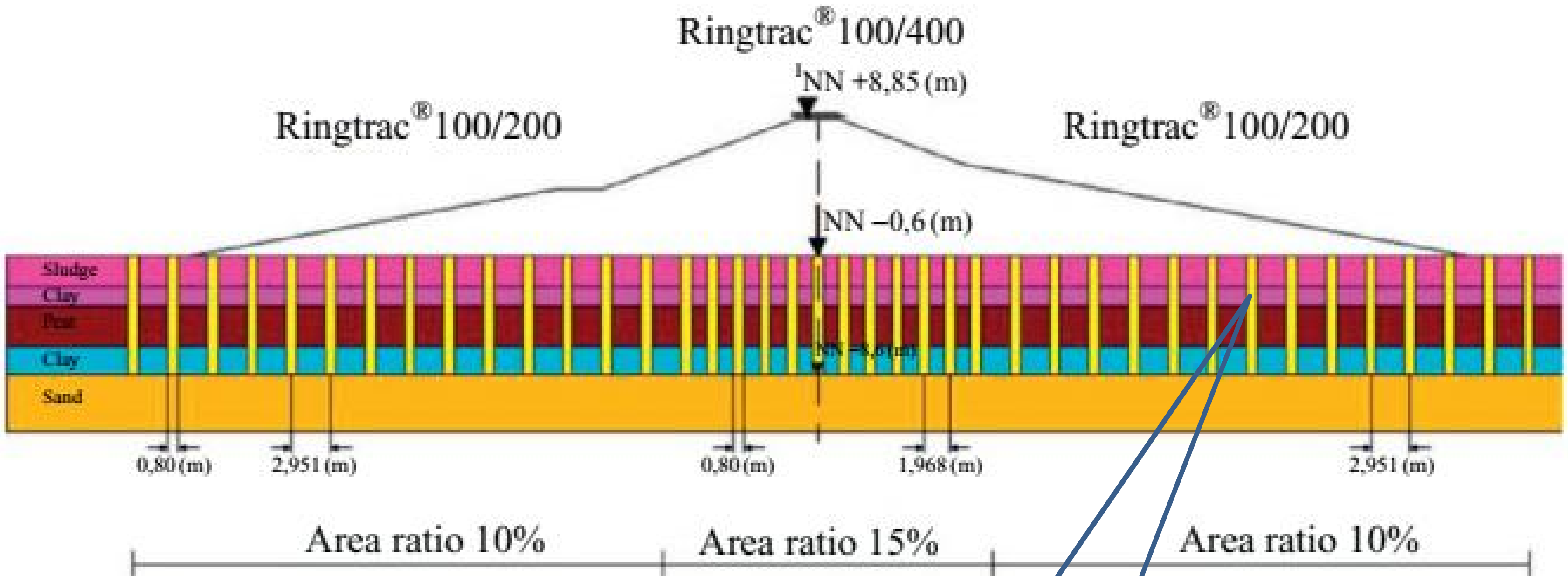
A heavy loaded railroad that runs to the harbor in Hamburg, Germany, required widening due to increasing traffic.

The GECs had a diameter of 1.54 m; the area ratio was in the range of 20–30%.



Application of Encased stone columns

Extention of Airbus site (2000-2002)



The extension was carried out by enclosing an area of extremely soft soils and with tidal changes by a 2.4-km-long dike.

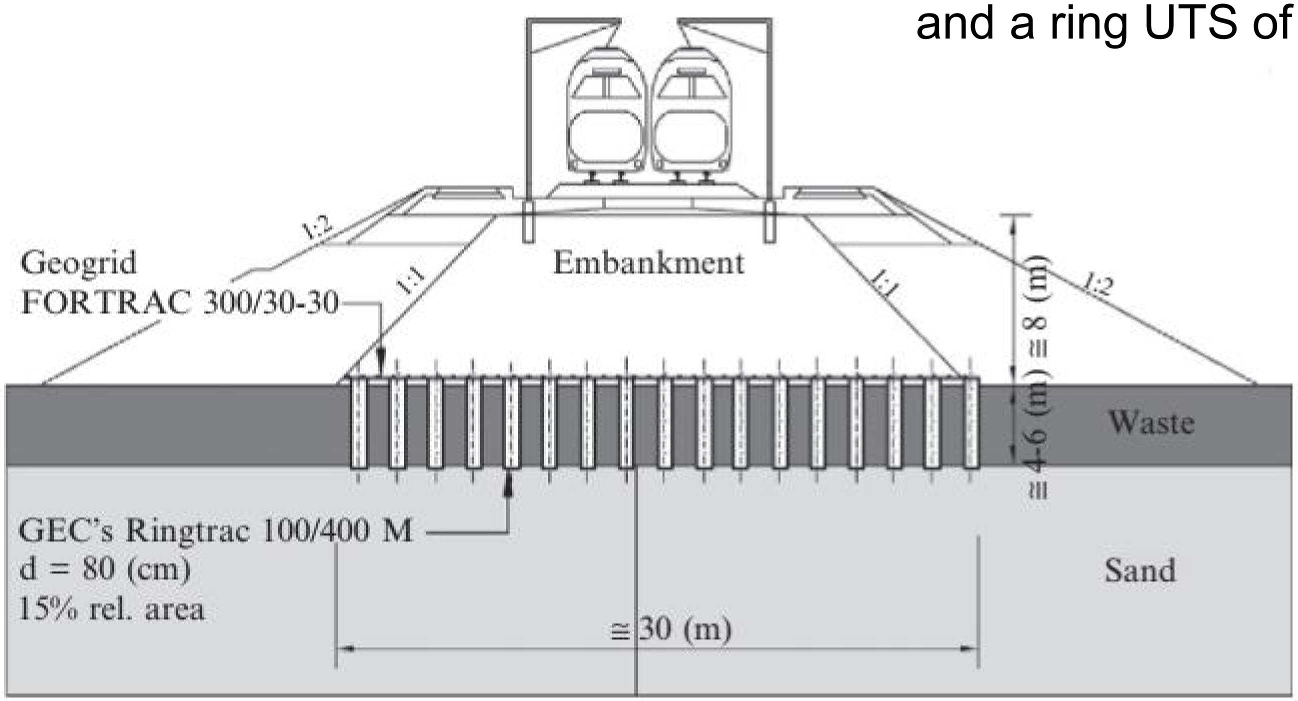
It is 60,000 GECS of a diameter of 80 cm and a total installed length of about 650 km.

Application of Encased stone columns

High-speed rail link (2002)

Railroad link (HSL) from Paris to Amsterdam at Westrick, Netherlands. The embankment was over some hundred meters of former waste disposal.

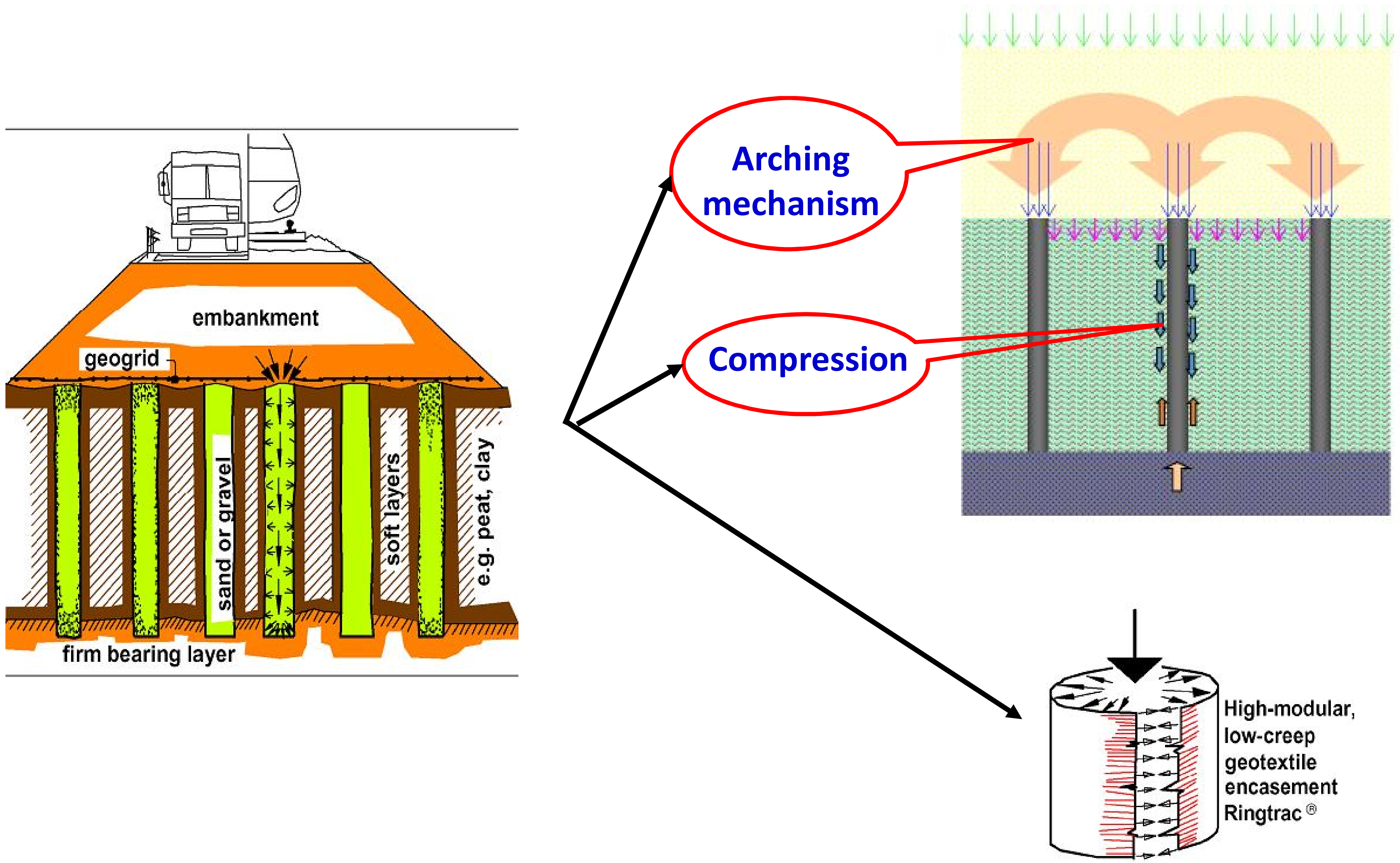
The GECs had a diameter of 0.8 m with an average replacement ratio of 15% and a ring UTS of 300 and 400 kN/m.



Application of Encased stone columns

year	project	construction	dam height [m]	soft soil [m]	∅ [cm]	method	A_C/A_E [%]
road and railroad construction							
1996	Waltershof	railroad embankment	5	5	154	excavation	25 - 30
1996	Baden -Baden	railroad embankment	4	5	65	displac.	20
1998	Bruchsal	road embankment	13	5	80	displac.	20
1998	Grafing	railroad embankment	3	10	80	displac.	17
1998	Saarmund	highway embankment	5.5	10	80	displac.	10
1998	Niederlehme	highway embankment	5	7	80	displac.	14
1999	Herrnburg	railroad embankment	40	11	80	excavation	15
1999	Tessenitz-Tal	highway embankment	5	10	80	displac.	10
2000	Krempe	bridge ramp	8	7	80	displac.	13-20
2000	Grafing	railroad embankment	2-4	6.5	80	displac.	15
2000	Sinzheim	railroad embankment	2	7	80	excavation	15
2001	Hoeksche Waard	test field	2-5	10	80	displac.	5-20
2001	s'Gravendeel	test field	5	10	80	displac.	15
2001	Brandenburg	bridge ramp	7	15	80	displac.	13-18
2001	Betuweroute	bridge ramp	7	8	80	displac.	10-15
2001	Botniabahn	bridge ramp	8	8	80	displac.	15
2002	Westrik	railroad embankment	7	6 (waste)	80	displac.	15
2003	Oldenburg	railroad embankment	1.5	6	60	displac.	15
water construction – EADS area extension							
2001 2003	polder enclos-ing dike	flood protection dike	9.5	14	80	displac.	10-20
2003 2004	'Finkenwerder Vordeich'	flood protection dike	9.5	12	80	displac.	15

Behavior of Encased stone columns reinforced soft soil



Geotextile: tension

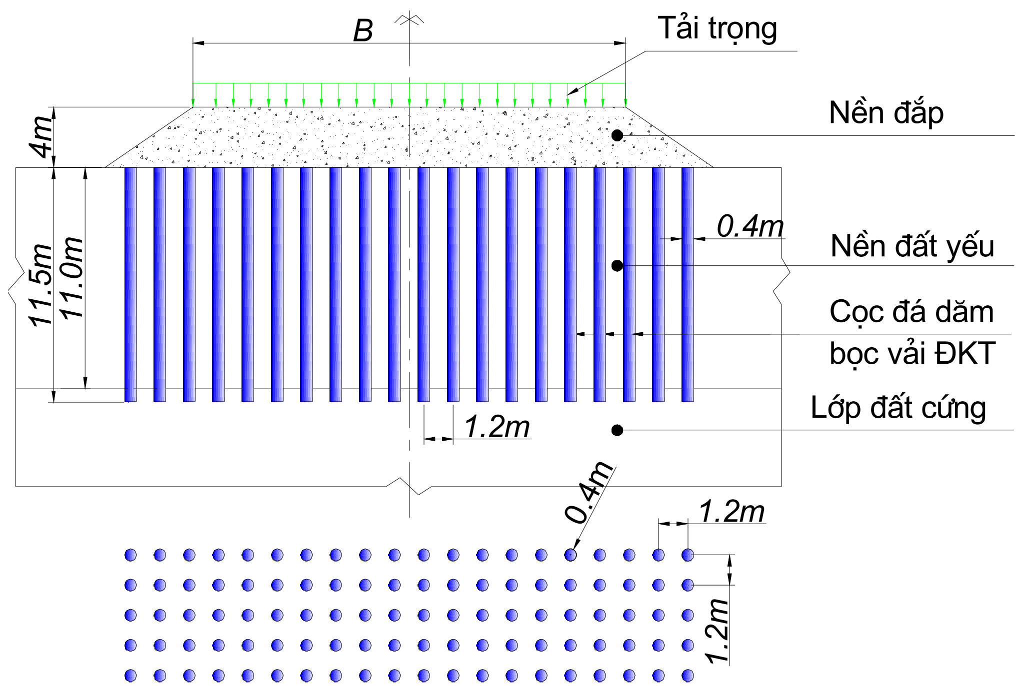
Behavior of Encased stone columns reinforced soft soil

Some points should be considered when design geotextile encased stone columns:

- Column spacing (improvement ratio) or column diameter;
- Column length;
- Embankment height;
- Embankment material;
- Stiffness and type of geotextile;
- Stone material.

A case study in Tan Vu – Lach Huyen

- At Km 3+675, in Tan Vu – Lach Huyen high way project.

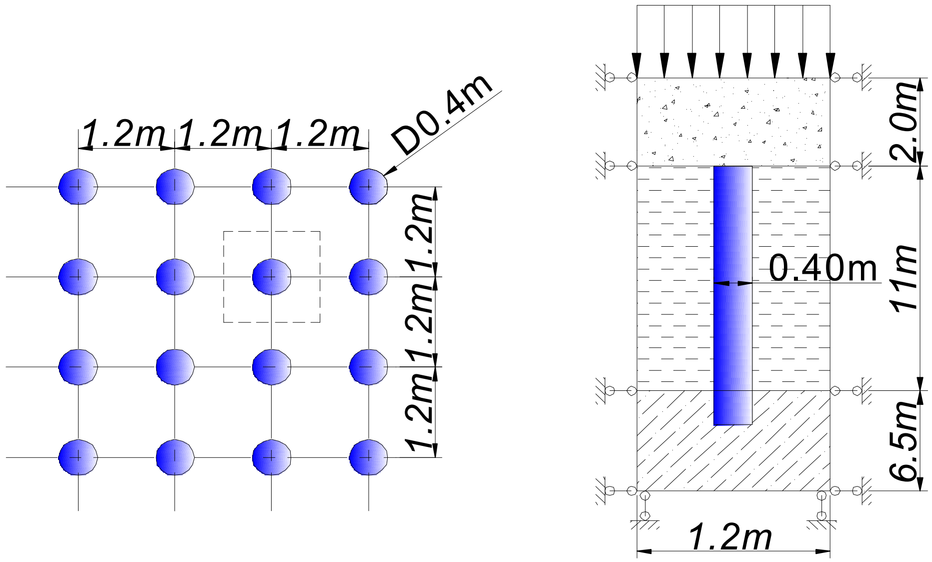


- Soils: 11 m soft silty clay, 6.5 m hard soil, and 12 m substratum.

- Colomns: D= 0.4 m and L= 11.5 m , column spacing =1.2×1.2 m. Stone columns are encased full length.

3D numerical modeling studies has been performed to make clear the effectiveness of GEC method compared to conventional stone column method.

3D numerical modeling procedure



Unit cell in 3D simulation

Code: FLAC3D

Constitutive models:

- Soft soil = modified Cam clay
- Embankment = Mohr-Coulomb
- Stone gravel = Elastic
- Geotextile = GEOGRID

Modified Cam-clay for soils in Nguyen et al. 2017

Soil layers	κ	ν	λ	M	e	γ (kN/m^3)
Extremely soft soil	0.03	0.3	0.187	0.621	1.379	16
Stiff clay	0.017	0.3	0.126	0.73	0.932	18

Mohr-Coulomb for embankment assumed in study of Do et al. 2013)

E (MPa)	ν	φ (°)	c (kPa)	ψ (°)	γ(kN/m^3)
150	0.3	40	0.0	0.0	18

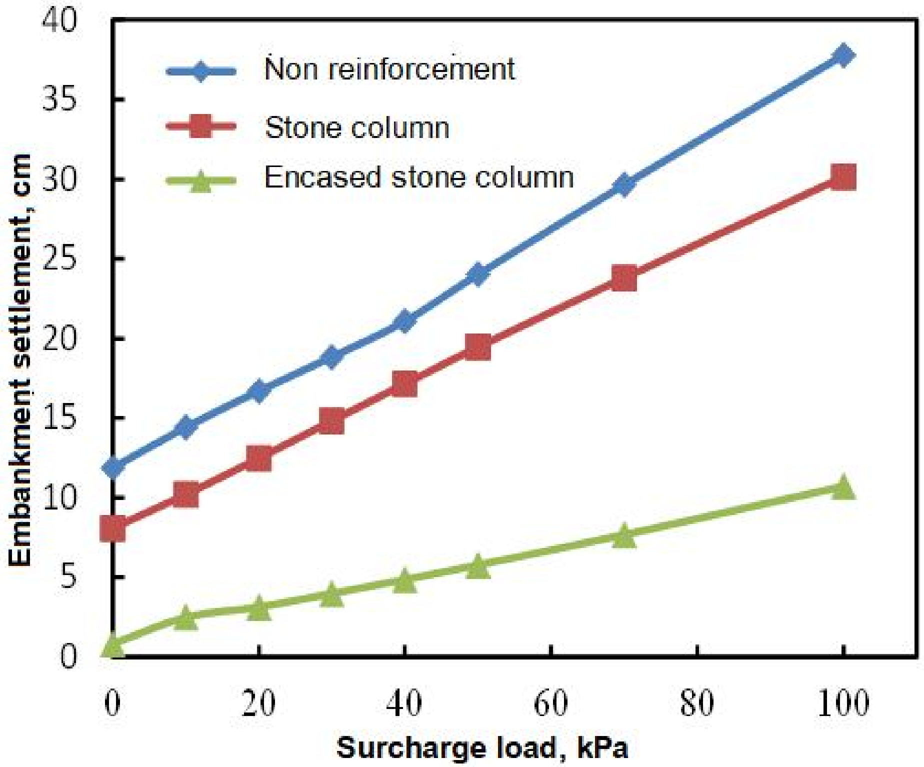
3D numerical modeling procedure

In the research, many studied cases are performed:

- A comparison of non-improved, stone column and encased stone column.
- The influence of applied load on embankment crest.
- The influence of improvement ratio

Numerical modeling results are shown in terms of **settlement** and **load transfer mechanism** of embankment, **radial column displacement**.

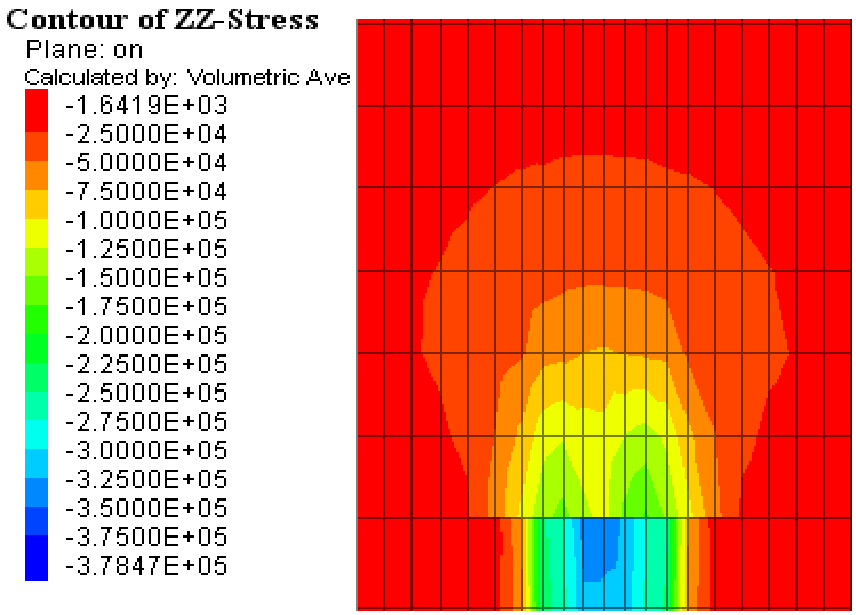
Numerical results - Embankment settlement



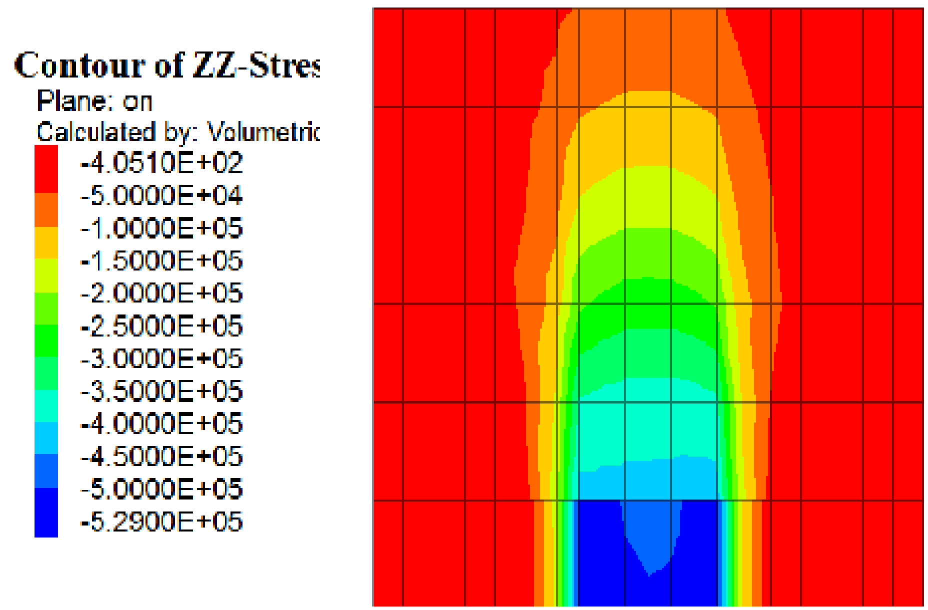
➡ Encased stone column method provides a significant reduction in embankment settlement

Load transfer mechanism on column head

Surcharge load, q = 20 kPa



a) Stone column



b) Geotextile encased stone columns

➡ More stress onto column head of geotextile encased stone column than that of traditional stone column is shown.

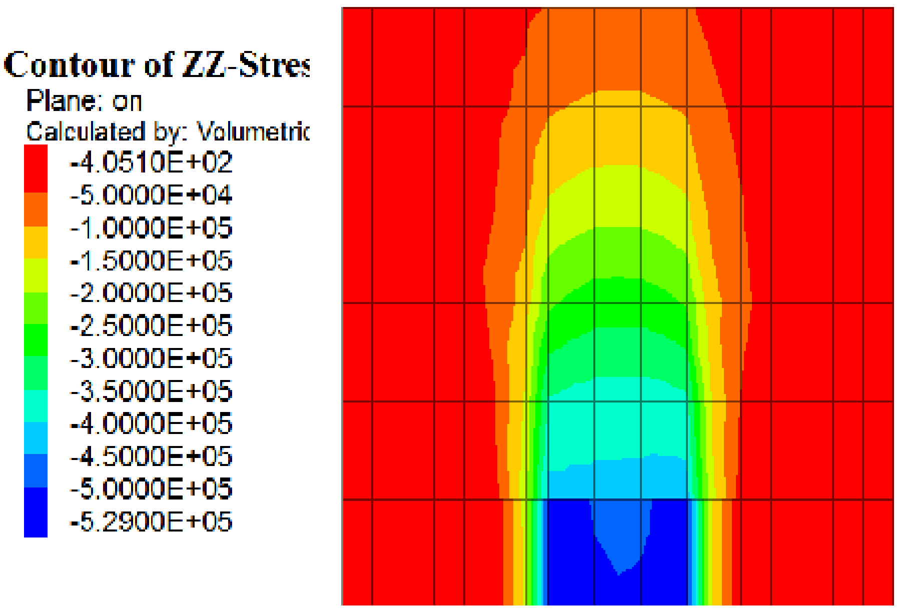
The applied stress onto column head is significantly higher than that on soft soil.

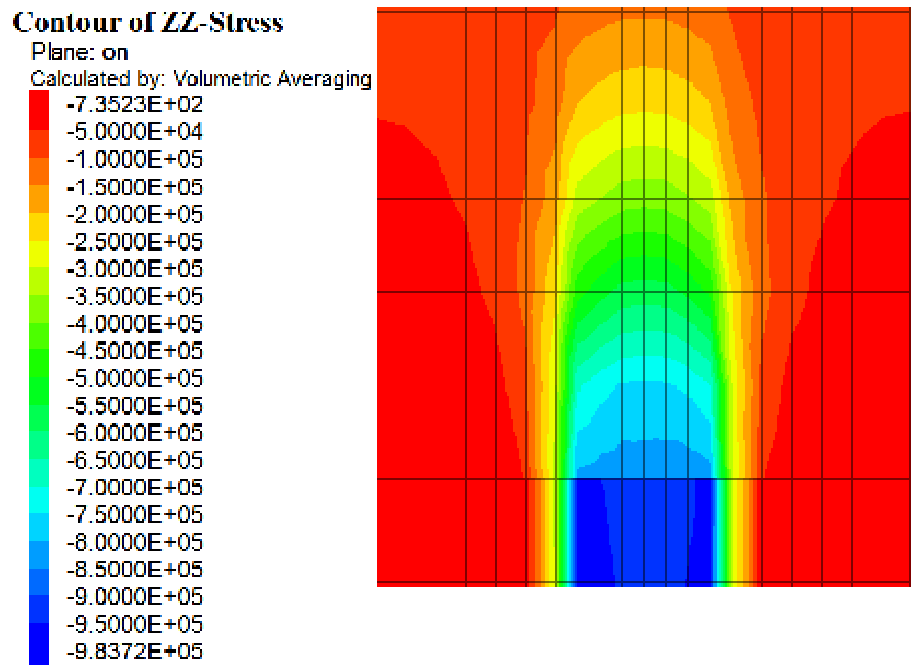
a)

Load transfer mechanism on column head

Surcharge load, q = 20 kPa

Surcharge load, q = 50 kPa



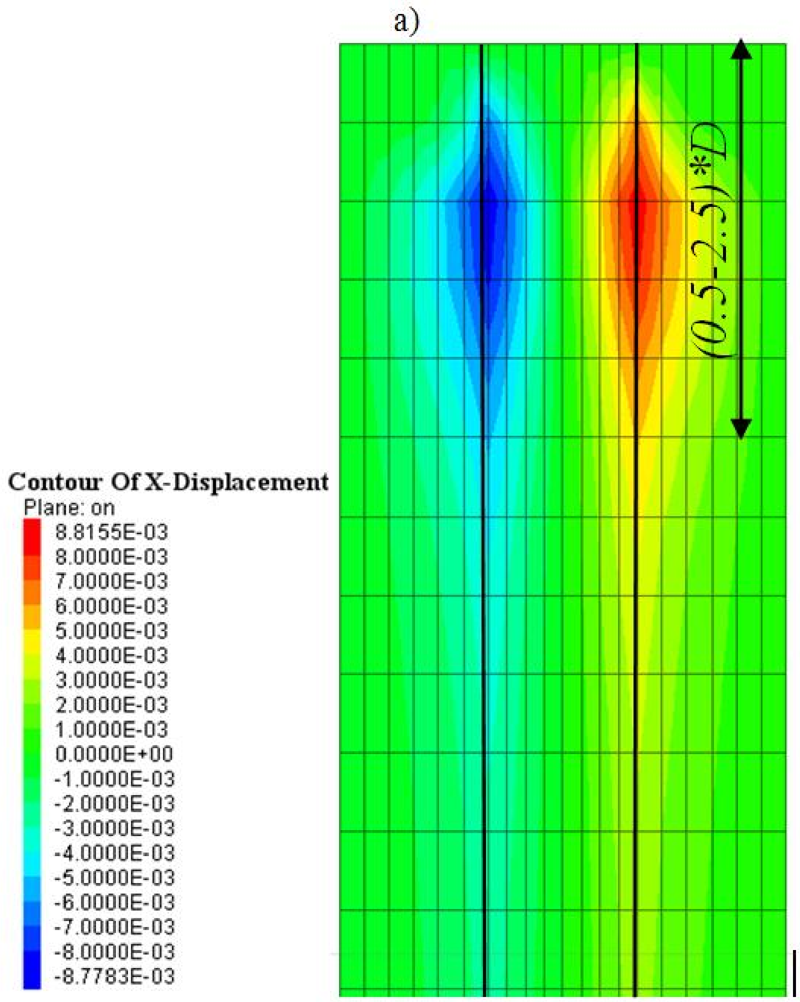


Geotextile encased stone columns

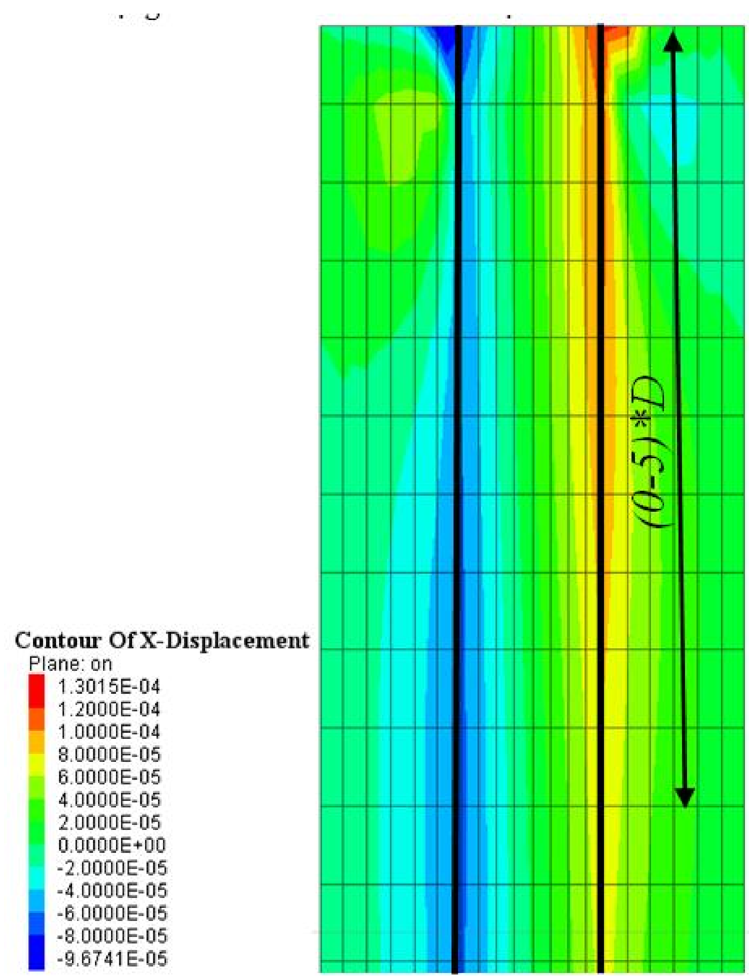
- An increase in the applied load on embankment induces a growth of column head pressure

Radial bugle displacement of columns

q = 50 kPa



Biến dang lớn nhất $\Delta d = 1.7\times10^{-2}$ mtai z = 1.5D= 0.6 m

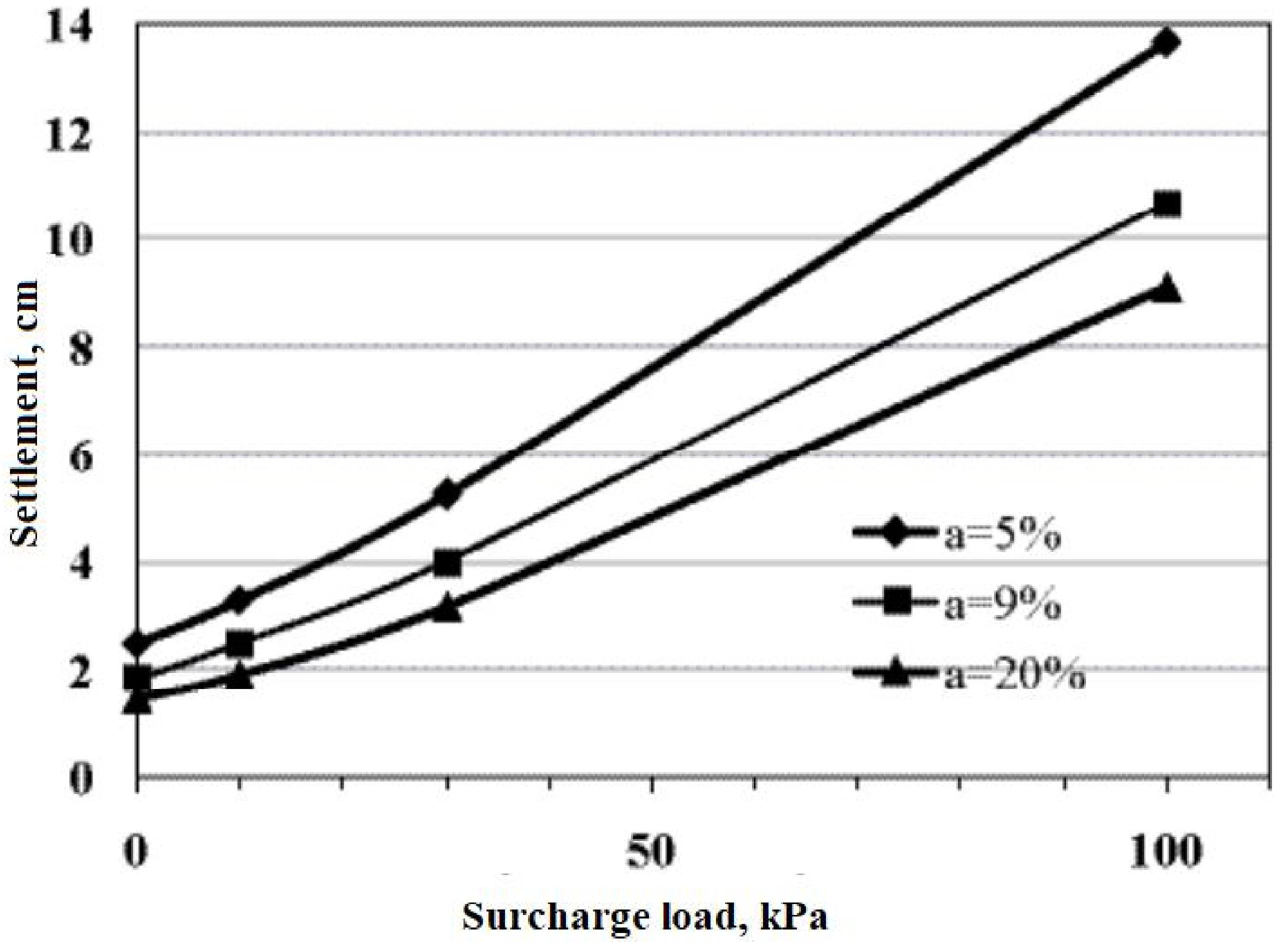


Biến dạng lớn nhất $\Delta d = 1.6\times10^{-4}$m tại z = (0÷5)$D$

➡ A significant decrease in radical displacement of column has been found, $\Delta d = 1.6\times10^{-4}$ m (only 1/100 value in stone column case).

a)

Influence of improvement area ratio



The total settlements decrease dramatically when the improvement ratio rises

a)

Conclusions

- The method has not applied in Vietnam yet. The designer should consider the encased stone column for soft soil improvement in coastal area.

- Use of geotextile encased stone column reduces the embankment significantly as compared to traditional stone column.

- More stress transfer to encased stone column than to stone column induces less stress onto soft soil.

- Radial displacement of encased stone column is really small as compare to traditional stone column.

Thank you for your attention!