




Authorized New Technology No.1079
Patent Licensed No.10-1426496

Tremendous Ground Reinforcement Technology
The Shortest, Simplest, Cheapest Way

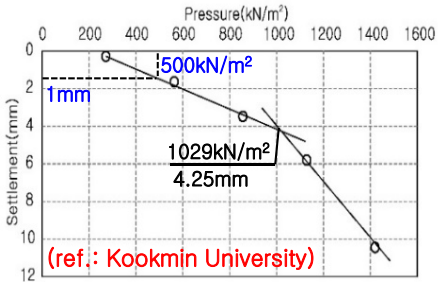
Puzzle Soil TRADEMARK

(Ground Replacement Technology by interlocking effect)

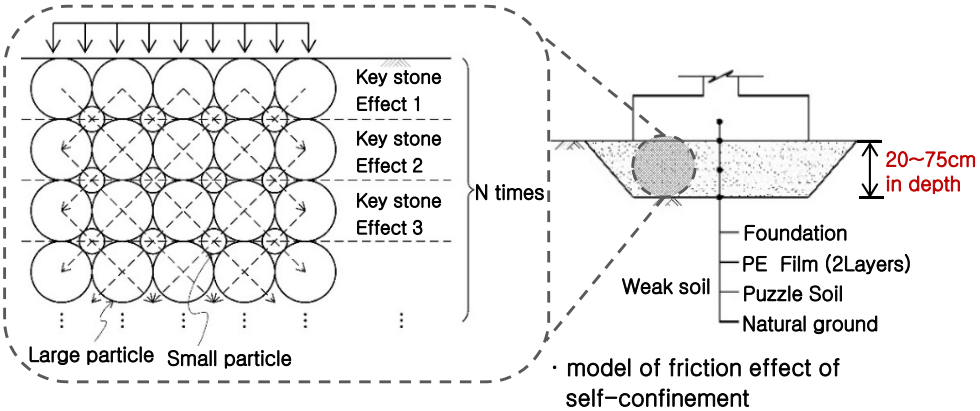
Reality model of Puzzle Soil (Sagot Beach in Korea)


· registered airfield on inter-national civil aviation organ-ization(ICAO)

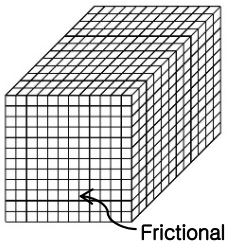

Plate Load Test
(Sagot Beach, Baekryeong island)



The Principle of Ground Reinforcement by Puzzle Soil



· model of friction effect of self-confinement

<Puzzle Soil>

<Capstan>

- interlocking effect by gap-grading of ground material
- 100% friction saturation by crushed stones
- Maximum soil bearing capacity & minimum ground settlement

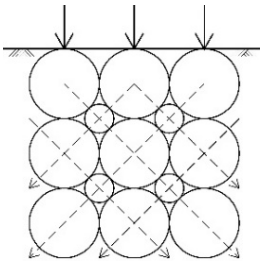
[Usage]

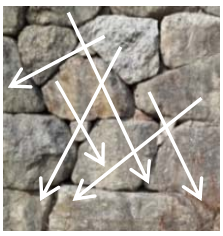
- S.O.G(Slab On Ground) for ware house, factory building, logistics center)
- for ground materials of underground structure (box culvert, drainage pipe)
- for ground replacement of basement parking lot & buildings
- for ground materials as sub-base of road & airfield
- for trafficability on soft ground

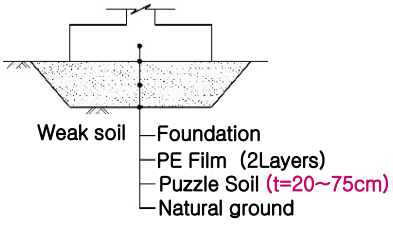
BUSIDDOL
Puzzle Soil Technique
www.puzzlesoil.net
Tel.02-6952-5537

What is Puzzle Soil?

■ Different sized crushed stones to be interlocked in any direction

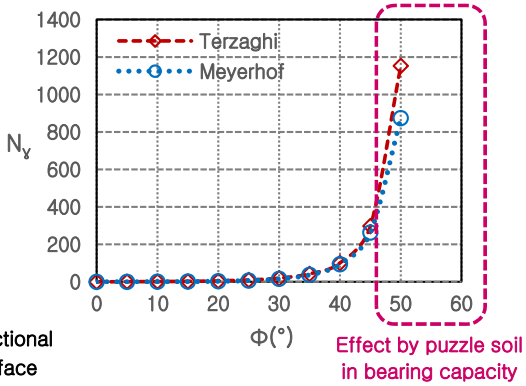




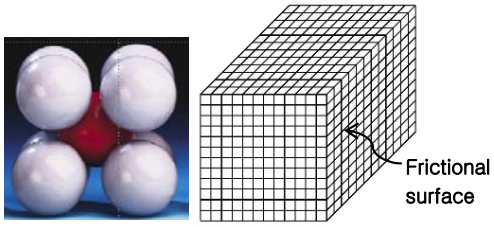


Terzaghi's formula for bearing capacity

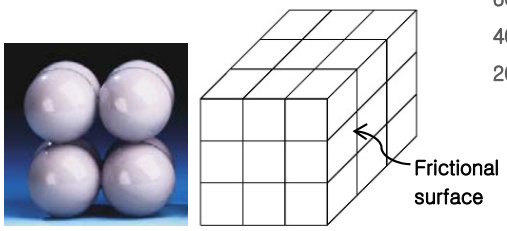
$$q_u = c \cdot N_c + \frac{1}{2}\gamma \cdot B \cdot N_\gamma + \gamma \cdot D_f \cdot N_q$$



<Puzzle Soil>



<General soil>

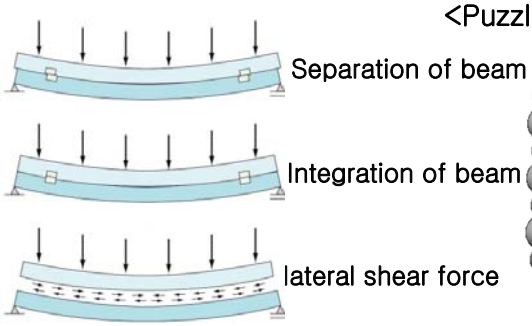


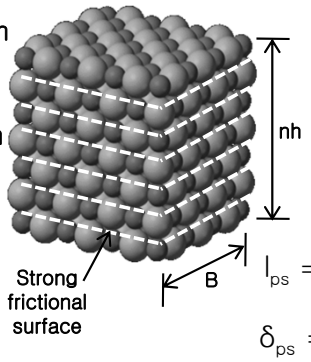
- natural crushed stones with over 50 degrees in friction angle
- Ideal Mix{ d=13, 19, 25mm of puzzle soils} + layer compaction = great replacement
- interlocking effect ⇒ increase of bearing capacity & decrease of settlement

Shorter ground replacement depth due to interlocking effect between granular puzzle soils

■ moment of interfia & displacement

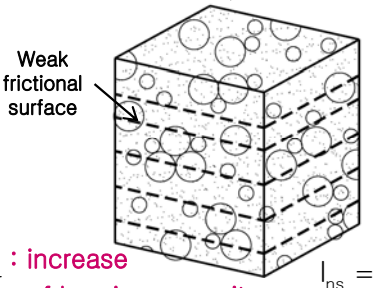
<Puzzle soil : integration of beam> <General soil : separation of beam>





$I_{ps} = \frac{B(nh)^3}{12}$: increase of bearing capacity

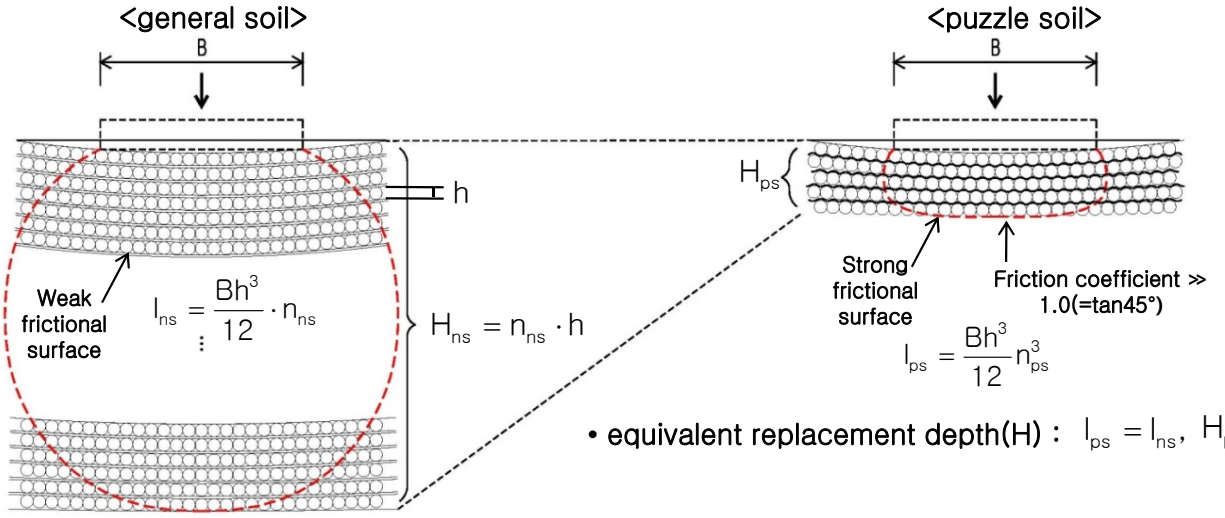
$\delta_{ps} = \frac{\delta_{ns}}{n^2}$: decrease of settlement



$I_{ns} = \frac{Bh^3}{12} \cdot n$

$\delta_{ps} = \frac{\delta_{ns}}{n^2}$

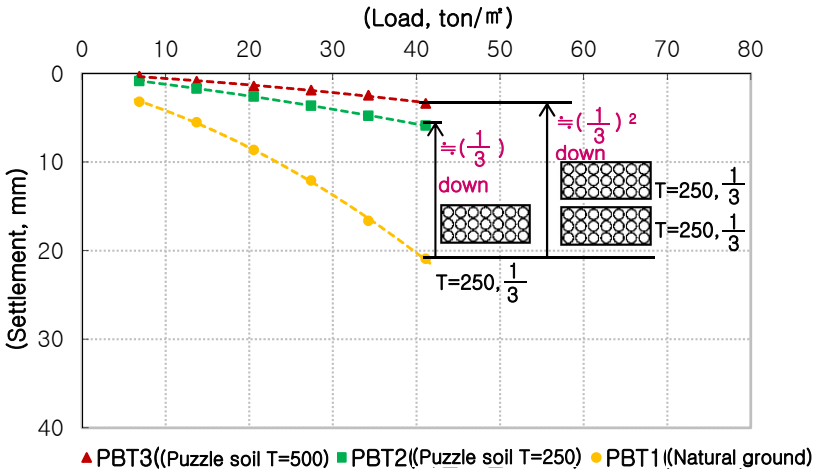
■ equivalent replacement depth : thinner replacement depth by puzzle soil



• equivalent replacement depth(H) : $I_{ps} = I_{ns}$, $H_{ps} = n_{ps}h = \sqrt[3]{n_{ns}}h$

Validation of replacement effect by puzzle soil

■ Validation of replacement effect in Ssang-yong motor site by various depth of puzzle soil



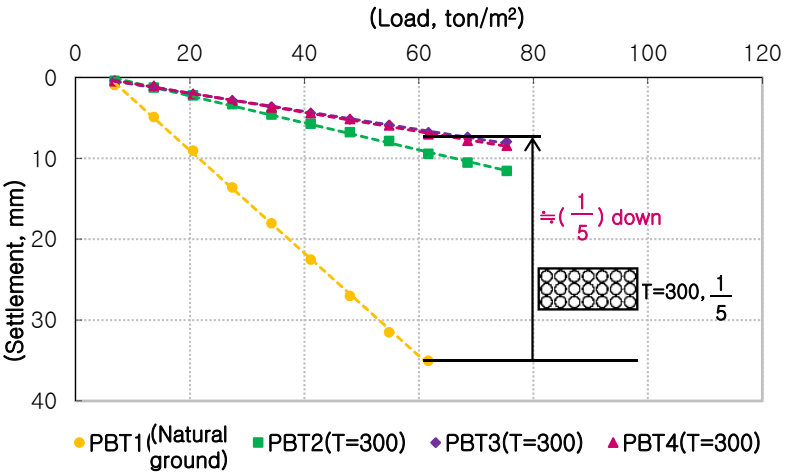
<PBT1:Natural ground>

<PBT2:Puzzle Soil 250mm>

<PBT3:Puzzle Soil 500mm>

– Φ=450mm plate for plate load test was used

■ Validation of replacement effect in Mapei factory by various depth of puzzle soil



<PBT1: PBT1:Natural ground>

<PBT2:Puzzle Soil 300mm>

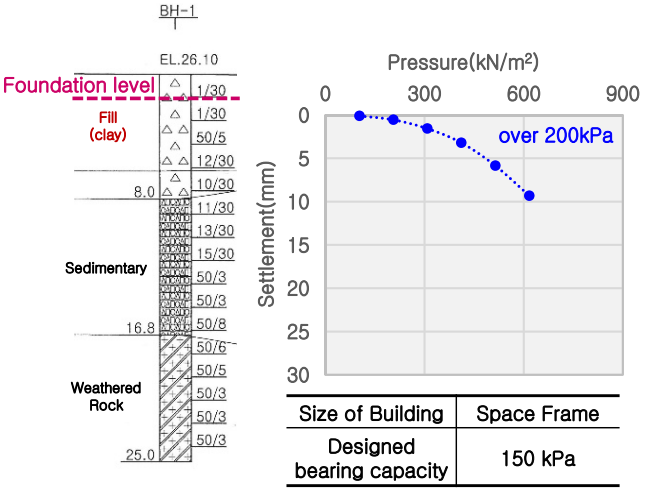
<PBT3:Puzzle Soil 300mm>

<PBT4: Puzzle Soil300mm>

– Φ=450mm plate for plate load test was used

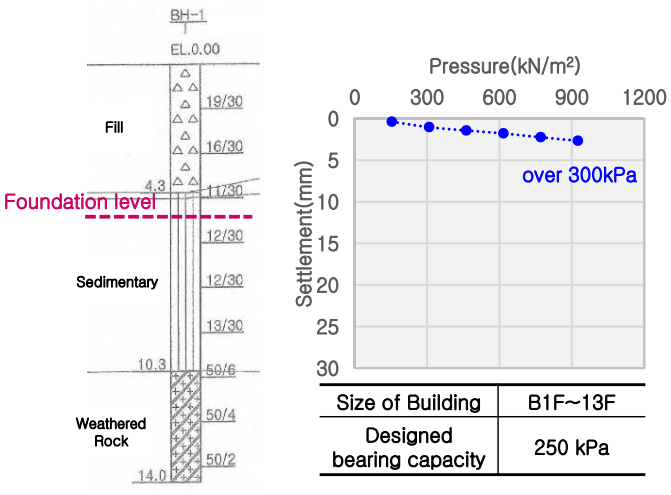
■ Replacement effect by puzzle soil

<Gate ball play ground in Hanam City>



Size of Building	Space Frame
Designed bearing capacity	150 kPa

<Dwelling house in Imun district>



Size of Building	B1F~13F
Designed bearing capacity	250 kPa

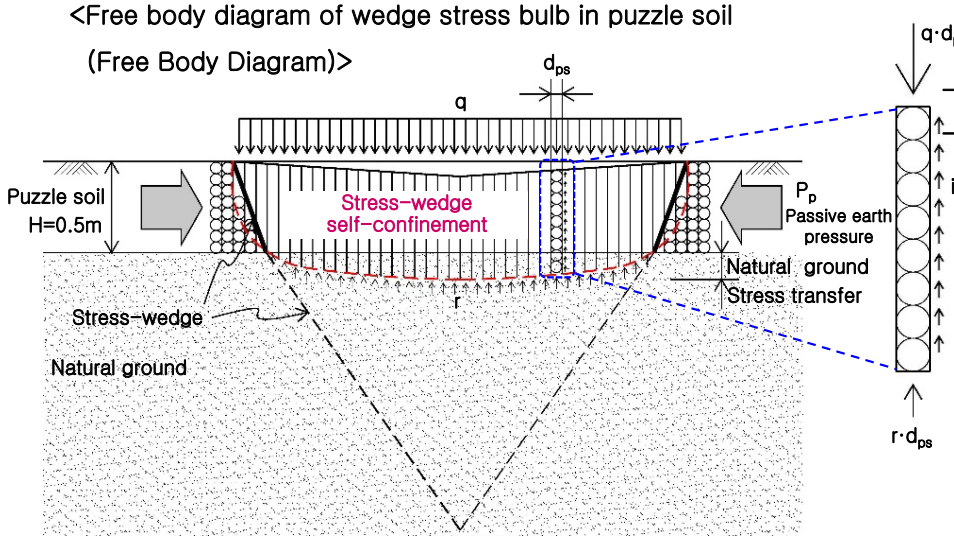
Wedge stress-bulb of Puzzle Soil

■ Interlocking force of puzzle soil and effect of stress distribution

• Minimum settlement by stress-distribution of puzzle soil

<Free body diagram of wedge stress bulb in puzzle soil

(Free Body Diagram)>



- d_{ps} = diameter of puzzle soil(ex: 25mm= $\frac{1}{40}$ m)
- F_s = safety factor of interlocking (=3.0)

equilibrium equation

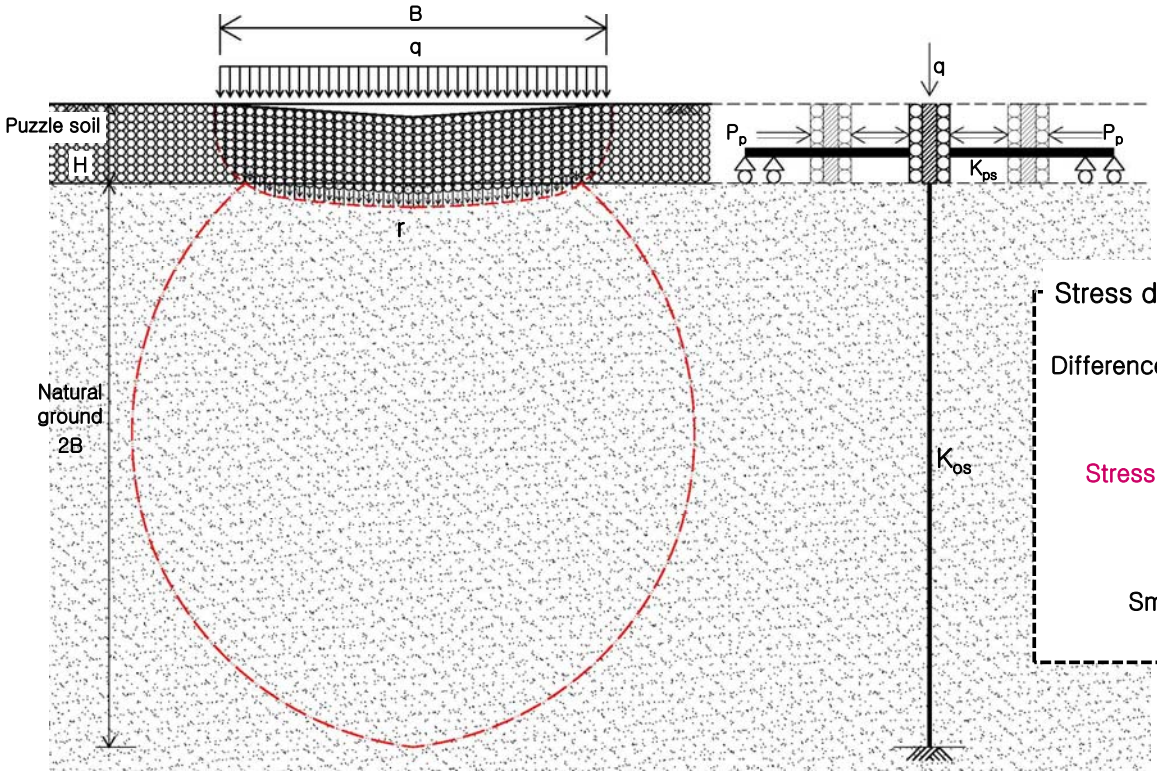
$$q \cdot d_{ps} = j + r \cdot d_{ps} \Rightarrow r = q - 2\frac{\tan \Phi \cdot P_p}{F_s \cdot d_{ps}}$$

for Φ=50°, H=0.5m, q_{max} = 54ton/m²

for Φ=55°, H=0.5m, q_{max} = 86ton/m²

for Φ=60°, H=0.5m, q_{max} = 144ton/m²

<Stress bulb of Puzzle soil>



Stress distribution by soil strength

Parallel,

Difference in soil strength($K_{ps} \gg K_{os}$)

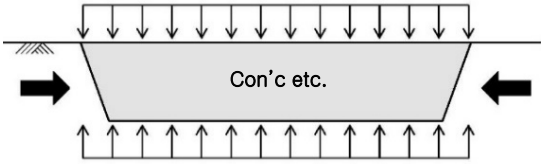
↓

Stress distribution($\sigma_{ps} \gg \sigma_{os}$)

↓

Smaller settlement, higher bearing capacity

<Free body diagram of concrete>

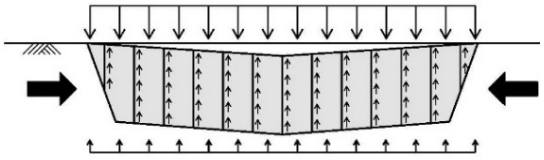


not allowable for inner displacement

not allowable for inner friction

concrete is a continuum

<Free body diagram of puzzle soil>



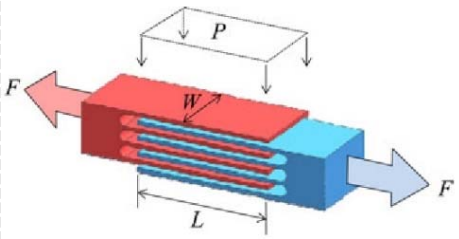
allowable for inner displacement

allowable for inner friction

Puzzle soil is a discontinuum

[Layer interlocking Concept]

- Effect of bigger frictional area



F = n·(μ·P ·w · L)

μ = coefficient of friction

n = number of layer

Puzzle Soil is the ground reinforcement technology using interlocking effect

■ Various examples of interlocking effect

<Overlapped book hard to tear>

• friction force

$$\frac{n(n+1)}{2} \text{ times}$$

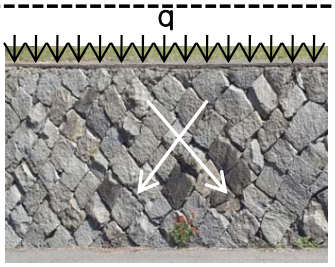
<Different resistant force with different types of twisted rope>

• Loose soil

• well-graded soil

• Puzzle soil

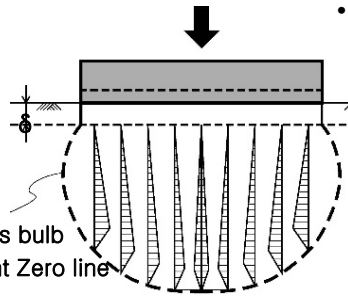
<Stone embankment>



< Sequence of frictional resistance of train >

• Car1, Car2, ··· frictional resistance will be occurred as needed in order

< Relative displacement inside stress bulb >



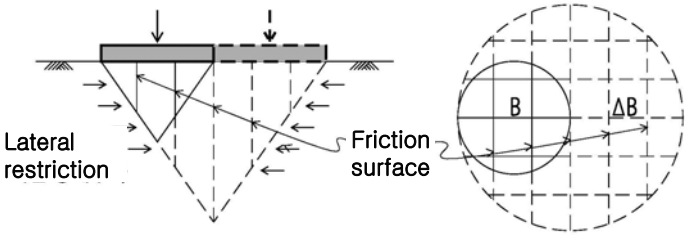
• Various relative displacement inside stress bulb → interlocking effect

< Rockbolt >

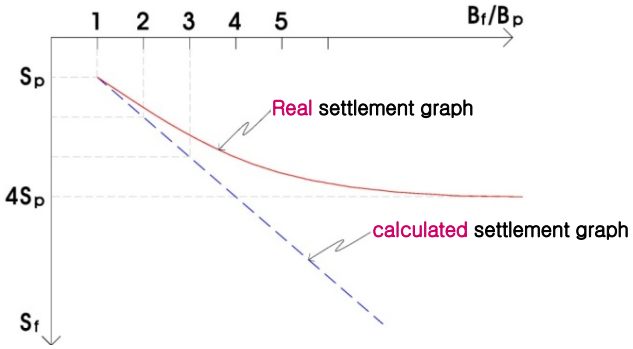
< Design criteria of foundation >

– Relation between load plate test and settlement of real foundation (by Terzaghi and Peck)

$$S_f = S_p \cdot \frac{4}{(1+ B_p/B_f)^2} \leq (2.5\sim4.0) \cdot S_p$$: low settlement due to many friction surfaces

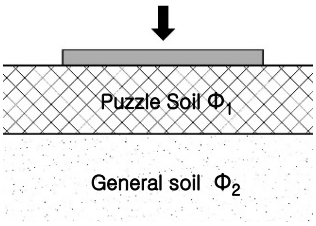


$$\frac{\text{Size of load}}{\text{Size of friction area}} = \frac{\text{area}}{\text{volume}} = \frac{1}{B}$$



■ Analysis of Bearing capacity by weighted average shear force

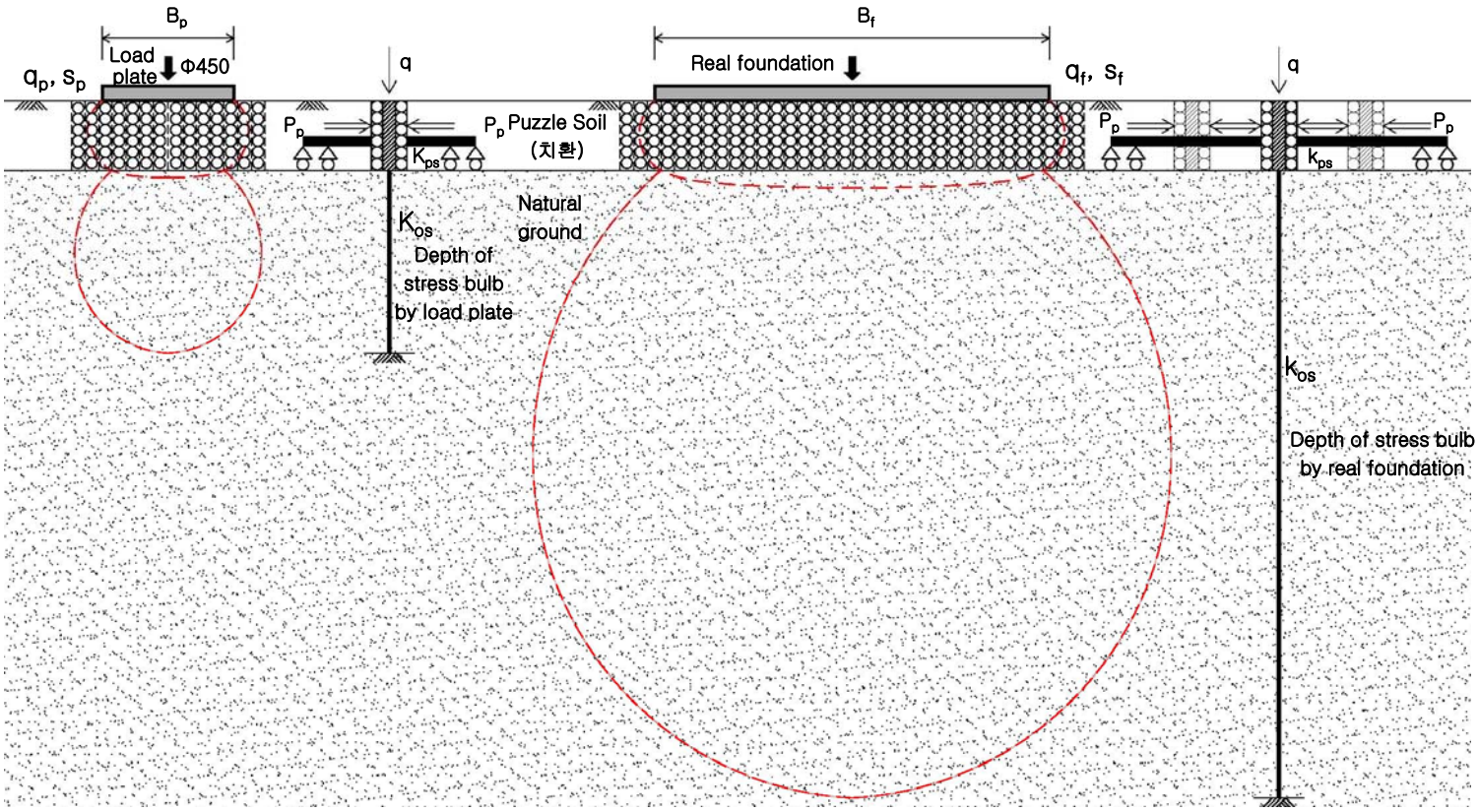
• Can be estimated by formula in hetero layer



$$\Phi_{av} = \tan^{-1} \frac{H_1 \cdot \tan\Phi_1 + H_2 \cdot \tan\Phi_2}{\Sigma H}$$

Puzzle Soil estimating long-term settlement

■ Compare stress bulb by load plate with stress bulb by real foundation



■ Calculation of settlement in soft ground considering stress-bulb($\sigma_{ps} \gg \sigma_{os}$)

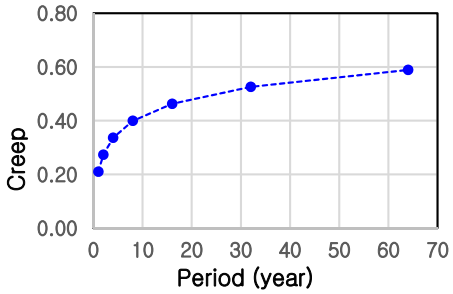
• Consolidation settlement

Consolidation settlement $S = \frac{C_c}{1+e_0} \cdot H \cdot \log\left(\frac{P_0 + \Delta P}{P_0}\right)$

• Immediate (elastic) settlement(Janbu, 1956)

$S_e = A_1 \cdot A_1 \frac{q_0 \cdot B}{E_u}$

■ Calculation of settlement by age of backfill layer



• Reflected creep settlement by puzzle soil's Know-how

■ Table of ground reinforcement effect by soil technology

content	Improved soil bearing capacity (kPa)						
USCS / N-value of SPT test	Coarse grained soils			Fine grained soils			
	clayey sand	silty sand	gravel sand	Clayey silt	Sandy silt	Silty clay	clay
~5	80~300	100~350	150~400	70~210	85~250	60~170	50~150
6~10	125~500	150~500	300~500	85~350	100~425	70~280	60~250
11~15	250~600	300~600	350~600	170~420	210~510	140~330	125~300
16~20	450~	500~	600~	310~	380~	250~550	225~500
21~25	500~	550~	600~	350~	425~	275~	250~
26	550~	600~	600~	385~	600~	300~	275~
remark	More accurate improvement in bearing capacity will be estimated with detail results of ground investigation.						

Excellence in performance of puzzle soils

■ Authorized new technology

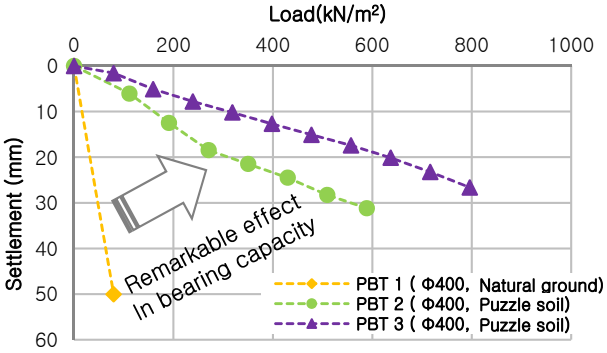
- Authorized by institute of new excellent technology in 2017 (NET)
- Title : Puzzle Soil is the ground reinforcement technology using interlocking effect
- The Korean Ministry of Defense adopted puzzle soil as technology demonstration for ground replacement

Authorized New Technology No.1079
Patent Licensed No.10-1426496

■ Validated ground reinforcement effect by test construction in An-sung

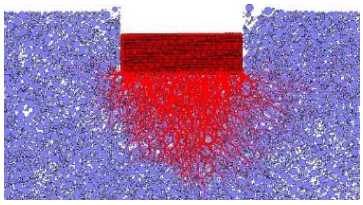
<PBT1 : Natural ground> <PBT2 : Puzzle soil > <PBT3 : Puzzle soil>

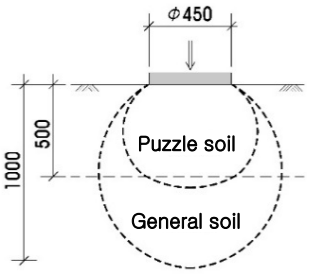




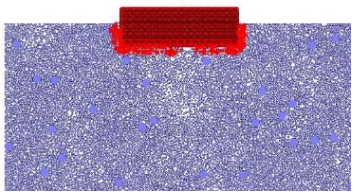
■ Computer simmulation

[general soil]

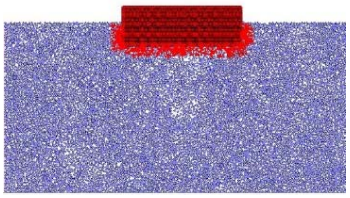




[Puzzle soil1]



[Puzzle soil2]



■ 공법비교표

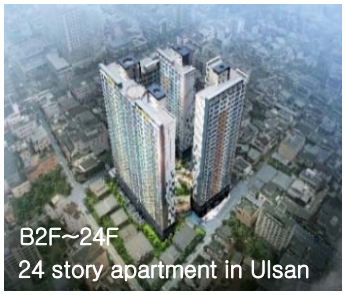
content	Puzzle soil	Top base	PHC pile
Picture			
Technique	• ground reinforcement by interlocking effect with different sized crushed stones	• ground reinforcement by top-base concrete foundation	• use PHC (Pretensioned High strength Concrete) pile
Merit	• high reinforcement effect over 1,000kPa with cheap price • Easy supply of materials • authorized new technology	• 1.2~1.5 times of bearing capacity than that of natural ground	• general technology in use but expensive
De-merit	• new technology • over 30 experienced cases	• poor compaction between each-top base foundation • minor improvement of ground reinforcement	• unsuitable in urban construction due to noise and vibration
Period	• simple constructional procedure & easy construction • thin replacement depth & short period	• not simple constructional procedure & long period • Concrete curing time is needed	• piling driver is needed
Cost	• $ 40~60/m² (replacement depth=0.5m)	• over $ 100/m²	• expensive • $200/m²

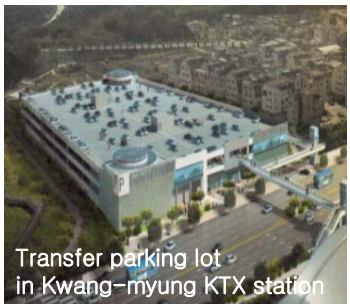
Records of construction achievements


B1F~9F
Dwelling house in Imun-dong


Icheon hospital in Kyung-gi do

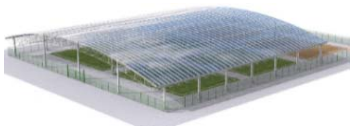

Strorage building in Jincheon


B2F~24F
24 story apartment in Ulsan


Transfer parking lot
in Kwang-myung KTX station


Mapei factory in Cheonan


B1F~13F
Song-jung apartment in Gumi


Gate ball play ground
in Hanam city

Project Name	Size
Ujin building in Seokyo district	5F
Seo-he apartment in Ansung	B2F~16F
Chenong-gi wa building in Cungge disrict	3F
Bojung dwelling house in Yong-in	4F
Jang-an ware house in Bo-eun	2F
Complex building in Bang-be district	B1F~5F
Buyung factory building in Ul-ju	2F
Dwelling house in Jang-jun district	3F
Multipurpose building in Yong-in	B1F~10F
Multipurpose building in Pusan	B1F~20F
Parking lot in dong tan district	B1F~8F
De-chang factory & company building	B1F~6F
Samsung SDS center in chun-cheon	4F

Project Name	Size
Complex building in On cheon district	10F
Officetel building in Sin dang district	B2F~13F
Tolykorea Factory	5F
Hwaseong Children's Cultural Center	B2F~4F
Mapei factory in Cheonan	2F
Icheon hospital in Kyung-gi do	B2F~5F
Jangchungdong Wangjokbal factory	B2F~3F
Dwelling house in Je-ju do	B1F~4F
Ssang-young motor factory	3F
Research facilities in Ma gok districr	B3F~8F
Complex building in Yeon-san district	B1F~15F
Dwelling house in Noeundong	B1F~6F
Werehouse in San-san district	4F

Etc.

Construction procedure of Puzzle Soil


1. Site survey


2. Excavation


3. Compaction


4. Deliver puzzle soils
(crushed stones) to site


5. Mixing puzzle soils
(with 2~3 different sized soils)


6. Spreading & compaction


7. Load plate test(Φ450mm)


8. Finalizing with PE film

NeT 신기술인증 NEW EXCELLENT TECHNOLOGY
Authorized New Technology No.1079
Patent Licensed No.10-1426496

Tremendous Ground Replacement Technology
The Shortest, Simplest, Cheapest Way

Puzzle Soil TRADEMARK
(Ground Replacement Technology
by interlocking effect)

◆Total management CEO : Kim, Kab boo
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E-mail : puzzlesoil@ puzzlesoil.net
◆ Construction Co. LTD. : Honeycell Enc
Tel. 82-2-561-0515