### Urban tree establishment in the Netherlands

Terra Nostra knowledge center for trees and soil



### Background



# Natural habitat

### Background





### Background





### No room for root growth, infiltration of rain and

### oxygen

### problems

- Drought
- Shortage of nutrients and oxygen
- Decreased growth and condition

![](_page_4_Picture_6.jpeg)

![](_page_4_Picture_7.jpeg)

# **Structural soil**

![](_page_5_Picture_1.jpeg)

### Properties

- Mixture of 80% stone and 20% soil
- Many different mixtures: variation in type of stone or composition of soil
- Organic matter 2-4%
- pH 5-7,5
- 20-30% pore volume

### Application

- Areas bearing a heavier load
- Bicycle paths, footpaths, parkingspaces, marketsquares

# **Structural soil**

### Type of stone

- Lava
- Mineral stone

Stonesize: 0-32, 16-32 mm

### Type of soil

- Clay
- Soil mixed with compost

### Stone/soil ratio

- 80/20 (most often used)
- 70/30

![](_page_6_Picture_11.jpeg)

- Soil quality
- Soil bacteria/fungi
- Ripe soil

![](_page_6_Picture_15.jpeg)

![](_page_6_Picture_16.jpeg)

### **Compaction – root growth** Ground penetrating radar

![](_page_7_Picture_1.jpeg)

![](_page_7_Picture_2.jpeg)

![](_page_7_Picture_3.jpeg)

Hand-dug tunnel
Pipe

![](_page_7_Picture_5.jpeg)

### **Compaction – root growth** Ground penetrating radar

![](_page_8_Picture_1.jpeg)

![](_page_8_Picture_2.jpeg)

![](_page_8_Figure_3.jpeg)

![](_page_8_Figure_4.jpeg)

# **Compaction – root growth**

![](_page_9_Picture_1.jpeg)

![](_page_9_Picture_2.jpeg)

### **Ground penetrating radar**

![](_page_9_Figure_4.jpeg)

Root density 0-30 cm

![](_page_9_Picture_6.jpeg)

# **Structural soil – root growth**

![](_page_10_Picture_1.jpeg)

![](_page_10_Picture_2.jpeg)

### **Evaluation of trees in structural soil**

![](_page_11_Picture_1.jpeg)

- Trees in structural soil based on mineral or lava stone
- A minimum of 5 years after planting
- 368 trees, 18 species, 24 locations in the Netherlands
- Parameters: condition, shoot length, damage to pavement, DBH growth

![](_page_11_Figure_6.jpeg)

![](_page_12_Picture_1.jpeg)

### YES!

- Apply well above (>20 cm) groundwaterlevel
- Apply and compact in layers of 30-40 cm
- Compact with a rammer or plate compactor
- Cover the tree growth site and storage site during rain

### NO!

- Apply in a waterlogged tree pit
- Apply at a moisture percentage of >20%
- Process structural soil during rain
- Apply a top layer on top of the structural soil of more than 20-30 cm

![](_page_13_Picture_1.jpeg)

![](_page_13_Picture_2.jpeg)

![](_page_14_Picture_1.jpeg)

8 cm paving 10 cm sand 30 cm base material Terri Nostri

structural soil

![](_page_15_Picture_1.jpeg)

![](_page_15_Picture_2.jpeg)

### Large toplayer on the structural soil

restricted aeration, water infiltration and root growth

### High groundwaterlevel/waterlogging in tree pit

- Could be temporary
- Anaerobic conditions
- Less detrimental if aeration/drainage in present

![](_page_16_Figure_7.jpeg)

- Growth decline
- Root rot
- Production of toxins
- Denitrification
- Decrease in soil microbes

Ter

# Compaction

![](_page_17_Picture_1.jpeg)

Level of

compaction?

### YES!

- Apply well above groundwaterlevel
- Apply and compact in layers of 30-40 cm
- Compact with a rammer or plate compactor
- Cover the tree growth site and storage site during rain

### NO!

- Apply in a waterlogged tree growth site
- Apply at a moisture percentage of >20%
- Process structural soil during rain
- Apply a top layer on top of the structural soil of more than 20-30 cm

# **Measurement of compaction**

### Sand-based structural soil

Penetrograph/penetrometer

### **Stone-based structural soil**

CBR test Nuclear densometer Falling weight deflectometer **Light Weight Deflectometer** 

Light Weight Deflectometer - LWD meter

- Measures the stiffness of the soil which correlates with a level of compaction
- Measurement up to 90 cm deep
- Fast measurement

![](_page_18_Picture_9.jpeg)

![](_page_18_Picture_10.jpeg)

### Light weight deflectometer

![](_page_19_Picture_1.jpeg)

### New tree growth sites

![](_page_19_Picture_3.jpeg)

### Existing tree growth sites

![](_page_19_Picture_5.jpeg)

# Development of new substrates

![](_page_19_Picture_7.jpeg)

![](_page_20_Picture_0.jpeg)

![](_page_21_Picture_0.jpeg)

![](_page_21_Picture_1.jpeg)

Surface

Below ground

Fall from half height 0-30 cm deep

Fall from maximum height 60-90 cm deep

![](_page_22_Picture_0.jpeg)

![](_page_22_Picture_1.jpeg)

Surface

Below ground

Fall from half height 0-30 cm deep

Fall from maximum height 60-90 cm deep Stiffness of the subbase material determines speed of the shockwave

The speed of the shockwave is converted to the **E0 modulus** 

![](_page_23_Picture_2.jpeg)

![](_page_23_Picture_3.jpeg)

Surface

Below ground

Fall from half height 0-30 cm deep

Fall from maximum height 60-90 cm deep

### E0 modulus

![](_page_24_Picture_1.jpeg)

- Elasticity modulus or Young's modulus
- Measures material stiffness
- Expressed as MPa
- Dependent on level of compaction and sub-surface material

![](_page_24_Figure_6.jpeg)

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![](_page_25_Figure_1.jpeg)

![](_page_26_Figure_1.jpeg)

![](_page_26_Figure_2.jpeg)

One type of structural soil:

Different E0 modulus Different level of compaction

![](_page_27_Picture_1.jpeg)

![](_page_27_Figure_2.jpeg)

E0 m odulus (M P a)

![](_page_28_Picture_1.jpeg)

![](_page_28_Figure_2.jpeg)

E0 m odulus (M P a)

### **E0 modulus –** influence of compaction

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![](_page_29_Figure_1.jpeg)

Typical values of Young's modulus for granular material (MPa) (based on Obrzud & Truty 2012 complied from Kezdi 1974 and Prat et al. 1995)

uscs	Description	Loose	Medium	Dense
GW, SW	Gravels/Sand well-graded	30-80	80-160	160-320
SP	Sand, uniform	10-30	30-50	50-80

### **E0 modulus of structural soil**

![](_page_30_Picture_1.jpeg)

![](_page_30_Figure_2.jpeg)

structural soil

# Structural soil – E0 value

![](_page_31_Picture_1.jpeg)

![](_page_31_Picture_2.jpeg)

# Structural soil – E0 value

![](_page_32_Picture_1.jpeg)

![](_page_32_Picture_2.jpeg)

# Structural soil – moisture

![](_page_33_Picture_1.jpeg)

![](_page_33_Picture_2.jpeg)

Optimum moisture content

— Wet side -

Moisture content %

Dry side -

![](_page_33_Picture_3.jpeg)

# Structural soil – moisture

![](_page_34_Picture_1.jpeg)

![](_page_34_Picture_2.jpeg)

Moisture levels: structural soil 18,5% soilfraction 21,8%

E0 structural soil 10-25 MPa

### Porevolume 12,4%

# Checklist for a tree growth site with structural soil

![](_page_35_Picture_1.jpeg)

### New tree growth sites

- Moisturelevel of the structural soil during storage
- Moisturelevel of the structural soil during application

Moisture measurement

- □ Storage of the structural soil on site ] supervision
- □ Way of compaction **supervision**
- □ Level of compaction ] LWD meter
- □ Measurement of pore volume In situ test

# Checklist for a tree growth site with structural soil

![](_page_36_Picture_1.jpeg)

### **Existing tree growth sites**

Compaction LWD meter

Measurement of pore volume In situ test

□ Soil nutrients ] Lab test

![](_page_37_Picture_0.jpeg)