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# Some recent development in quality control tests for prefabricated vertical drains (PVDs)

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*TC211 Workshop, 14th Asian Regional Conference, HK, 27 May 2011*

# Outline

- **Quality control (QC) for PVDs is not only a construction, but also a design requirement. Why?**
- **What are the QC tests for PVDs?**
- **Recent developments**
  - Better PVD products
  - Direct measurement of PVD installation depth

# Design Requirement

With pure radial flow, the average degree of consolidation, $U_h$, reached at a certain depth, z, can be calculated by:

$$U_h = 1 - \exp\left(-\frac{8c_h t}{\mu D^2}\right)$$

$$\mu = \ln\left(\frac{D}{d_s}\right) + \frac{k_h}{k_s}\ln\left(\frac{d_s}{d_w}\right) - \frac{3}{4} + \pi z(2l_m - z)\frac{k_h}{q_w}$$

$$d_w = 2(a+b)/\pi$$

**Well resistance**

**Discharge capacity of PVD**

# Minimum Discharge Capacity Required

- The condition for well resistance to be insignificant is:

Discharge factor

$$D = \frac{q_w}{k_h l_m^2} \geq 7.85$$

$$q_{req} \geq 7.85 F_s k_h l_m^2$$

$F_s$ = factor of safety, $F_s$ = 4~6

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# QC tests required

- For PVD selection and design, it is necessary to ensure the PVDs to have
  - ***Sufficient discharge capacity*** so that the well resistance can be ignored as is assumed in the design;
  - ***Sufficient tensile strength*** so that the PVD will not break or experience necking during installation;
  - ***A low unit cost*** as it leads to a huge amount of saving when millions meters of PVDs are used;
  - To ensure the ***design specifications are met*** in the construction, e.g., to install PVD to the required depth.

# Discharge Capacity Tests

- ASTM 4716 is NOT the standard for discharge capacity test, although it is often used.
- The drain to be tested SHOULD be embedded into soil.
- The test MUST have independent water head measurements.

# Straight Drain Tester

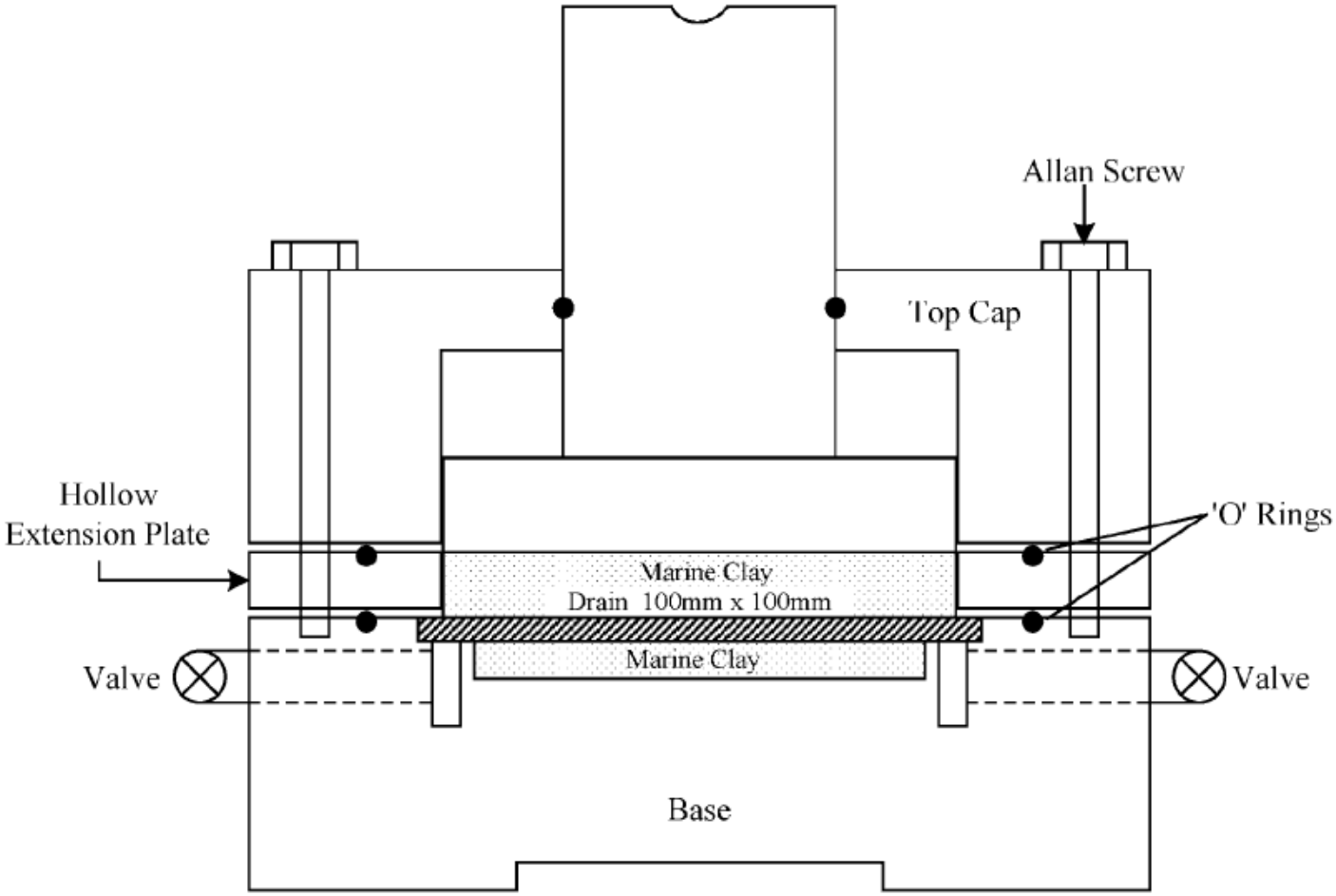
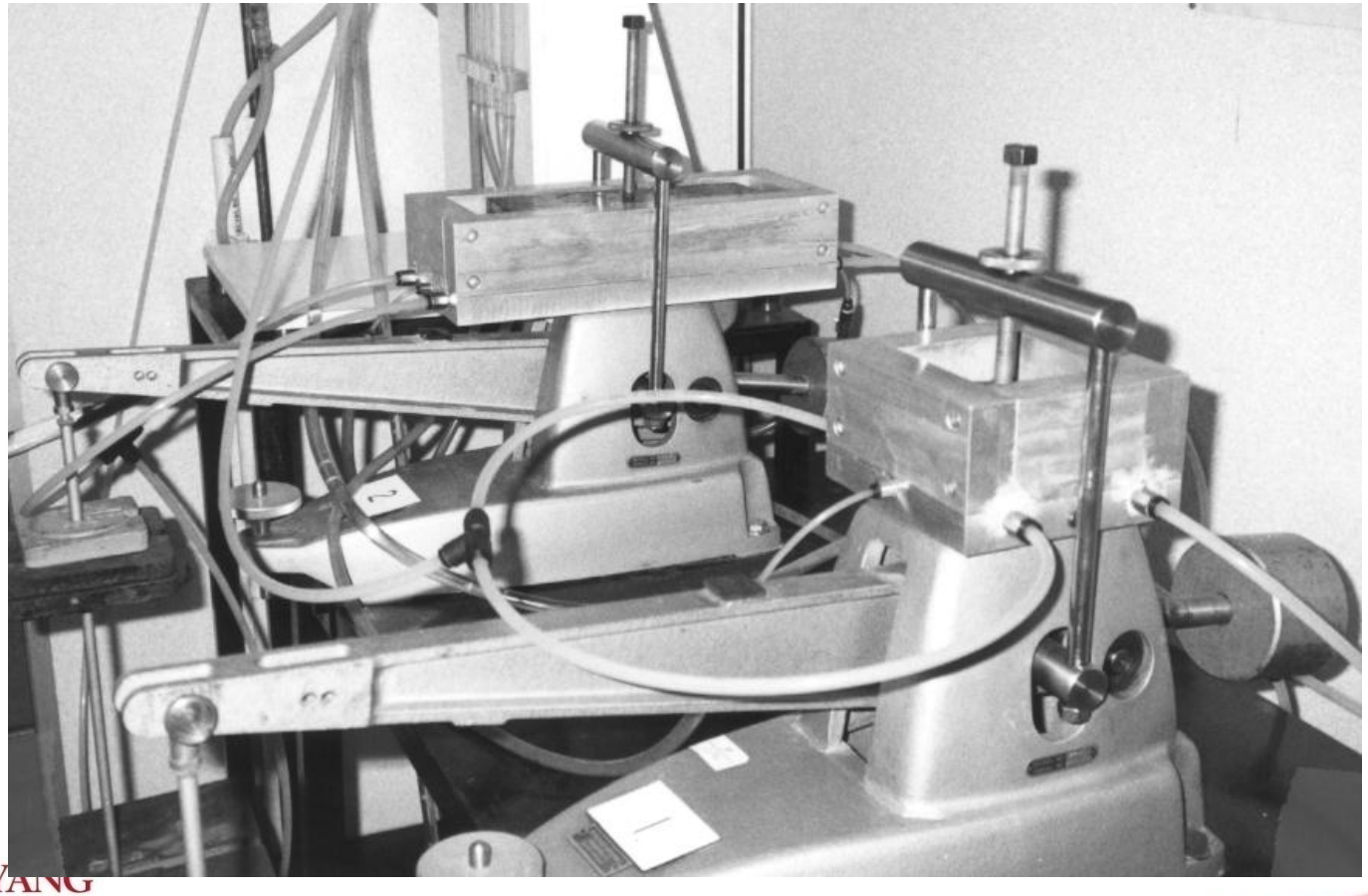
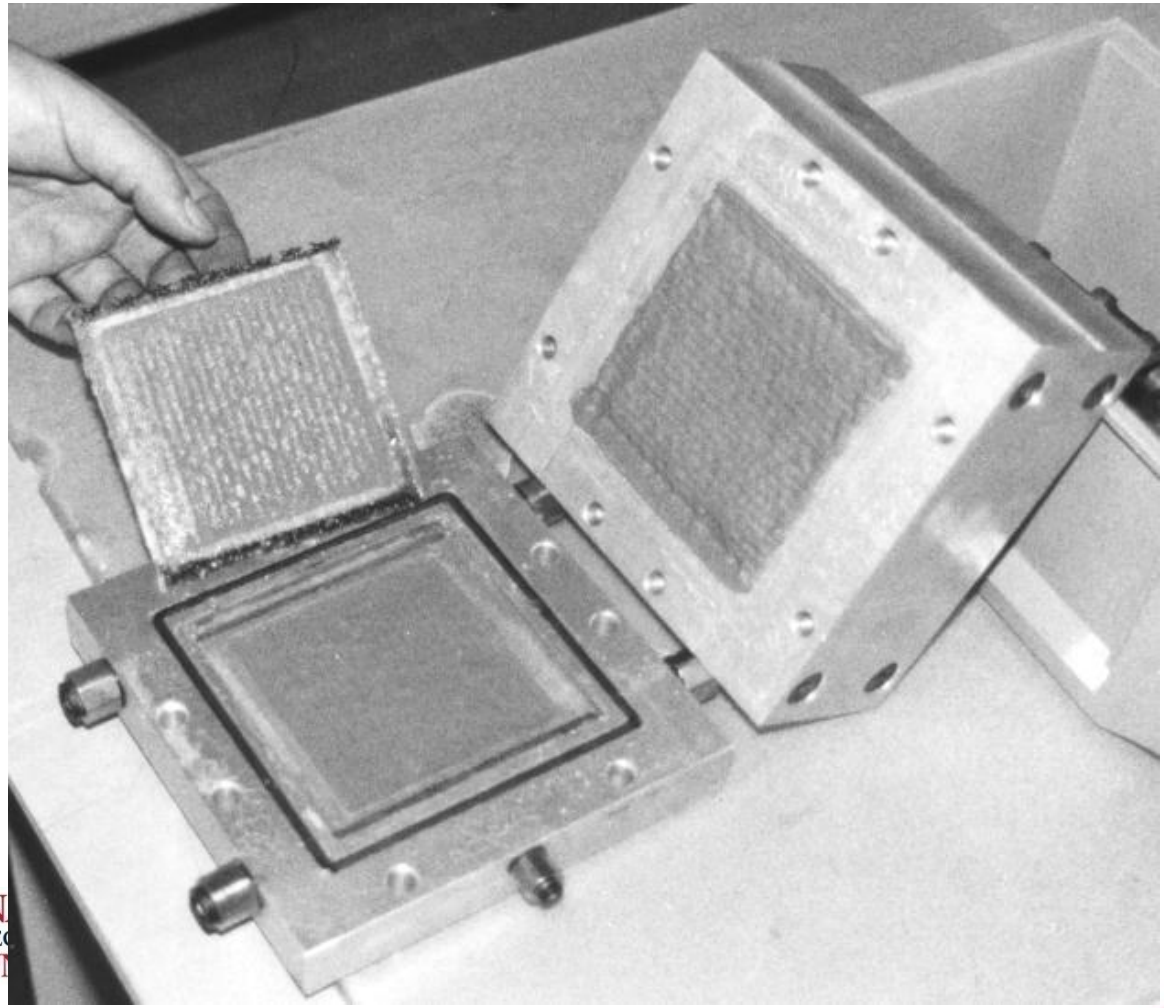



Fig. 4. A cross-section of the straight drain tester.

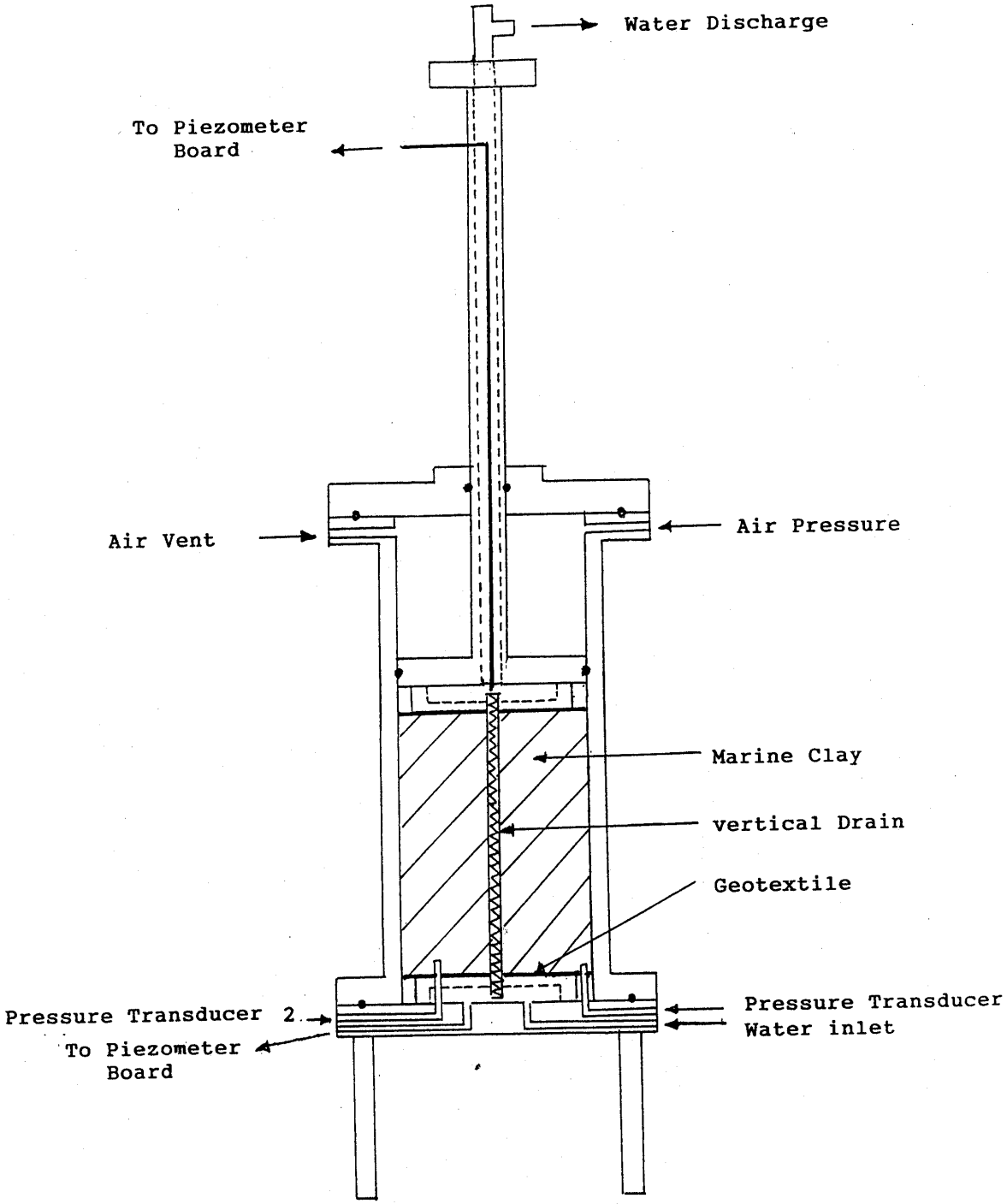
# Straight Drain Tester (Cont'd)



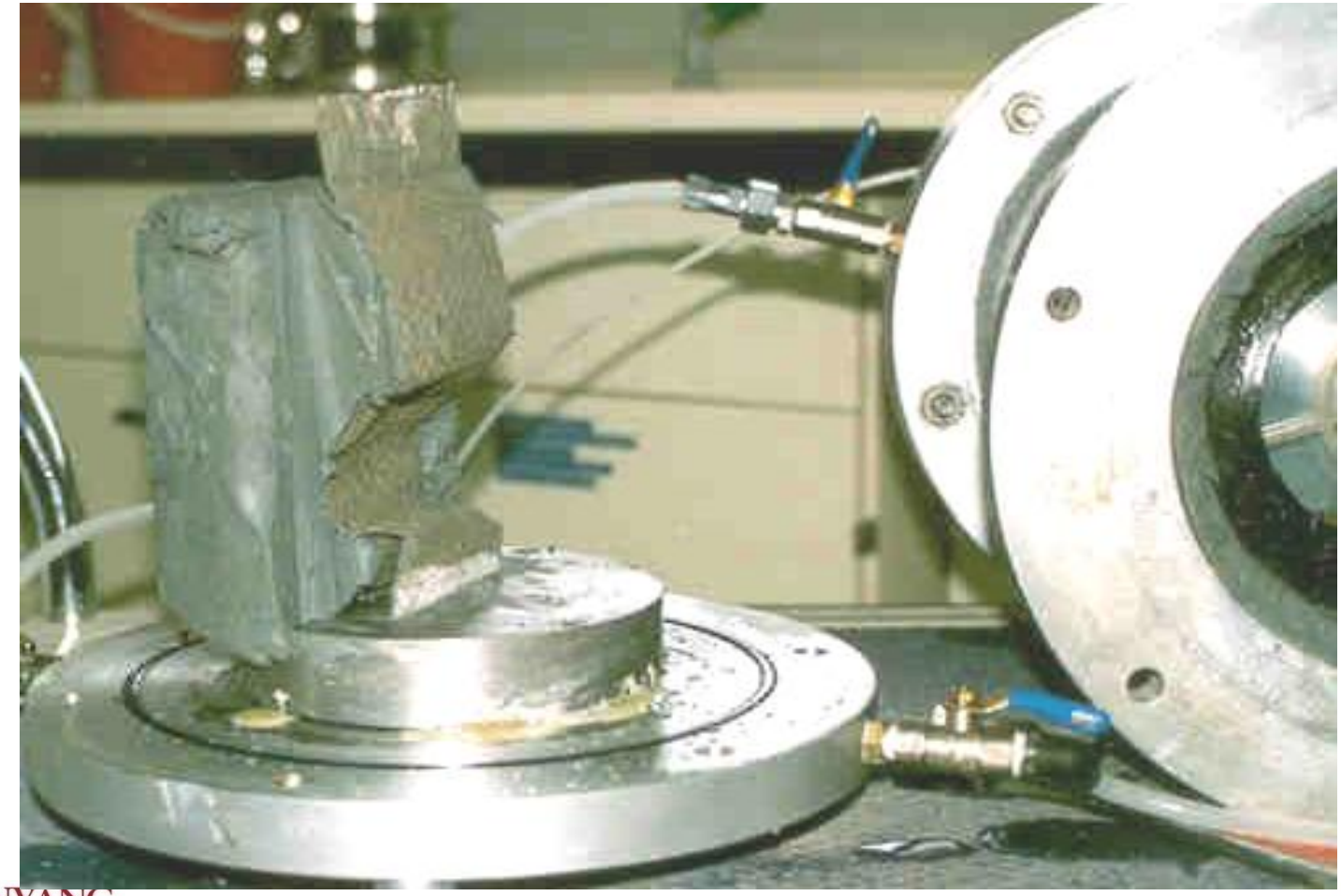
# Straight Drain Tester (Cont'd)



# Buckled Drain Tester



# Buckled Drain Tester (Cont'd)



# Tensile Strength Test

# Permeability of Filter

$$k = \frac{Q\delta}{A\Delta ht} R_t$$

As specified by ASTM D4491-96, the permeability is taken as the value corresponding to a 50 mm water head.

# AOS of Filter

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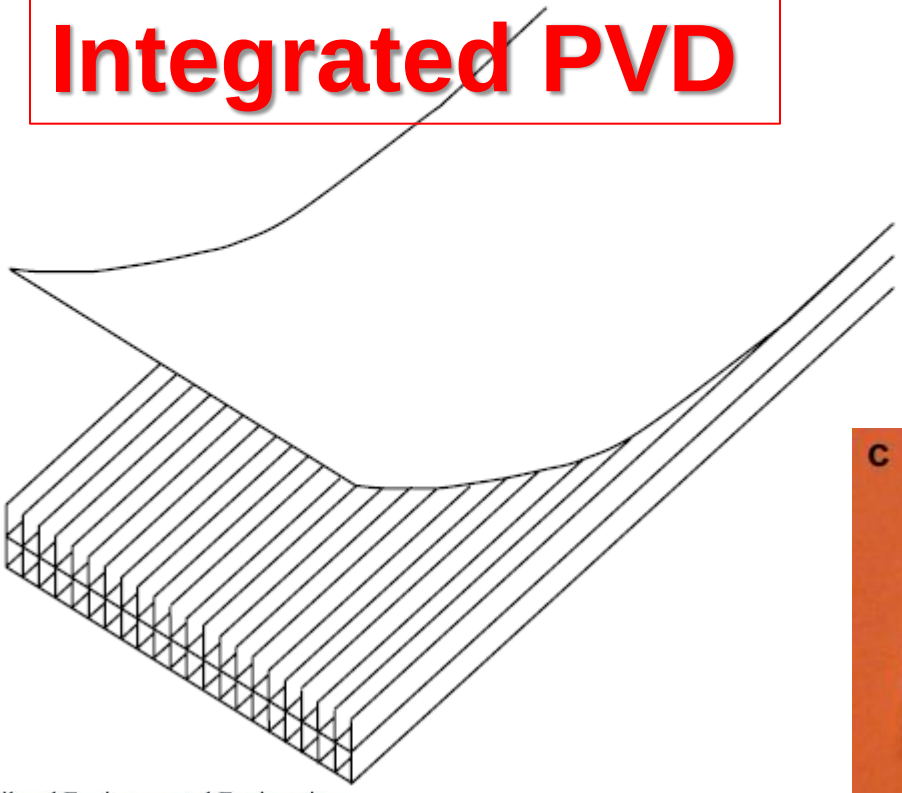
# Integrated PVD



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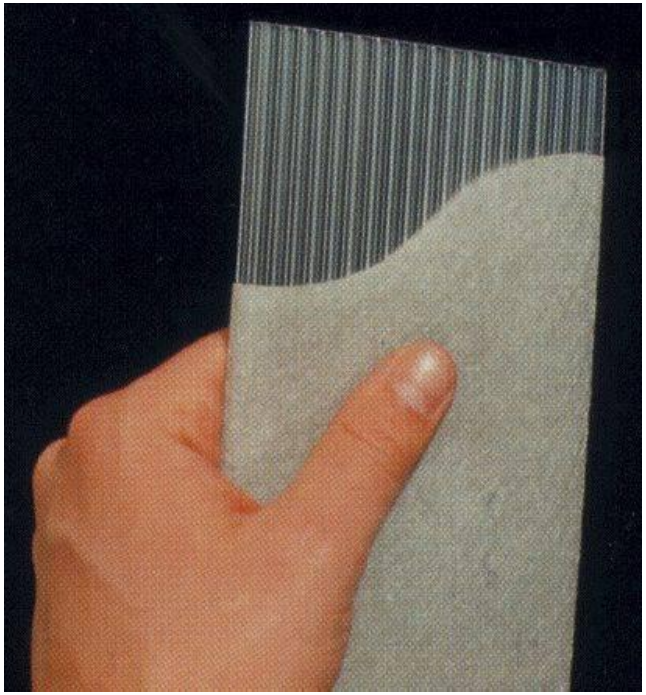
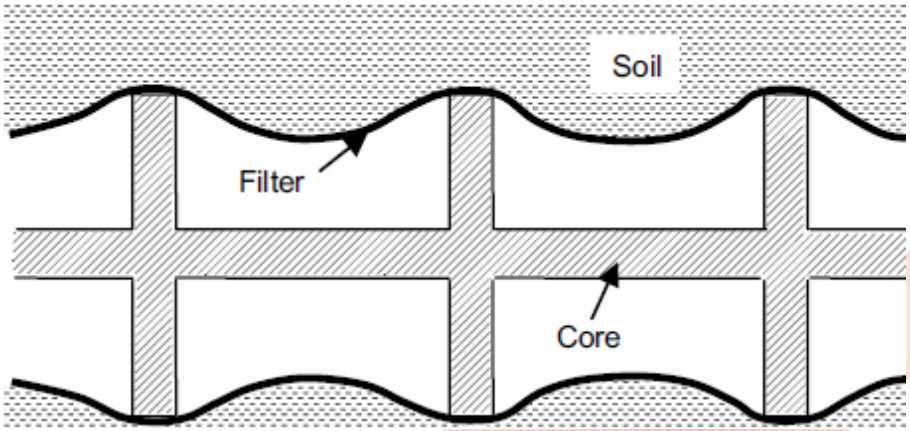
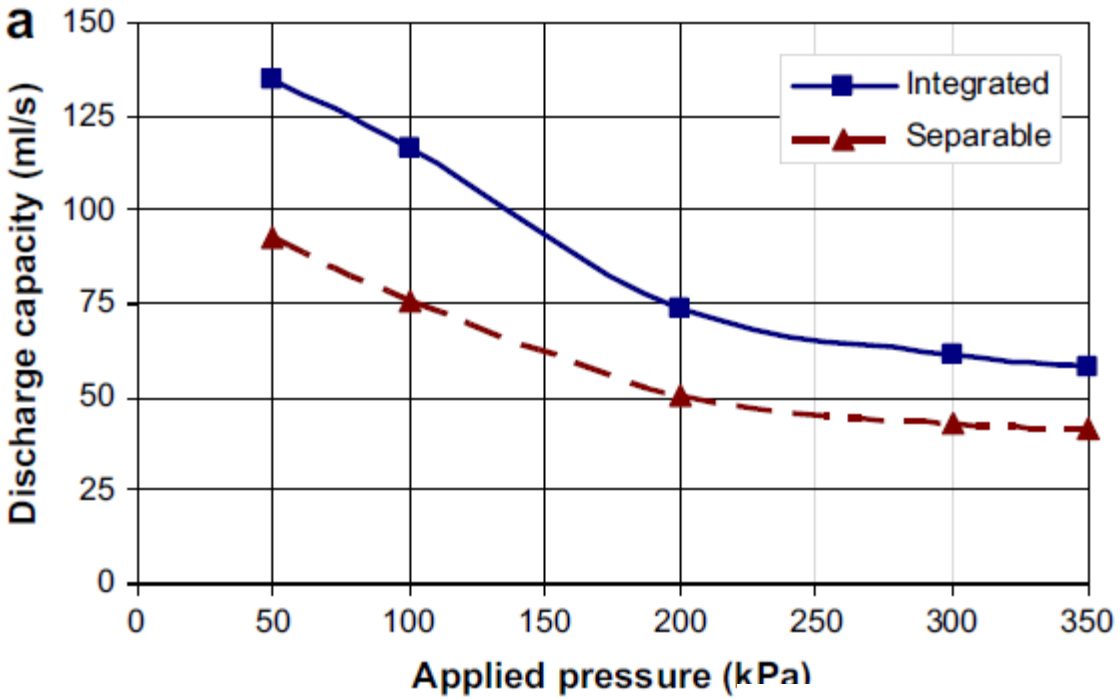


**Filter and core are adhered together by heat melting**

# Advantages

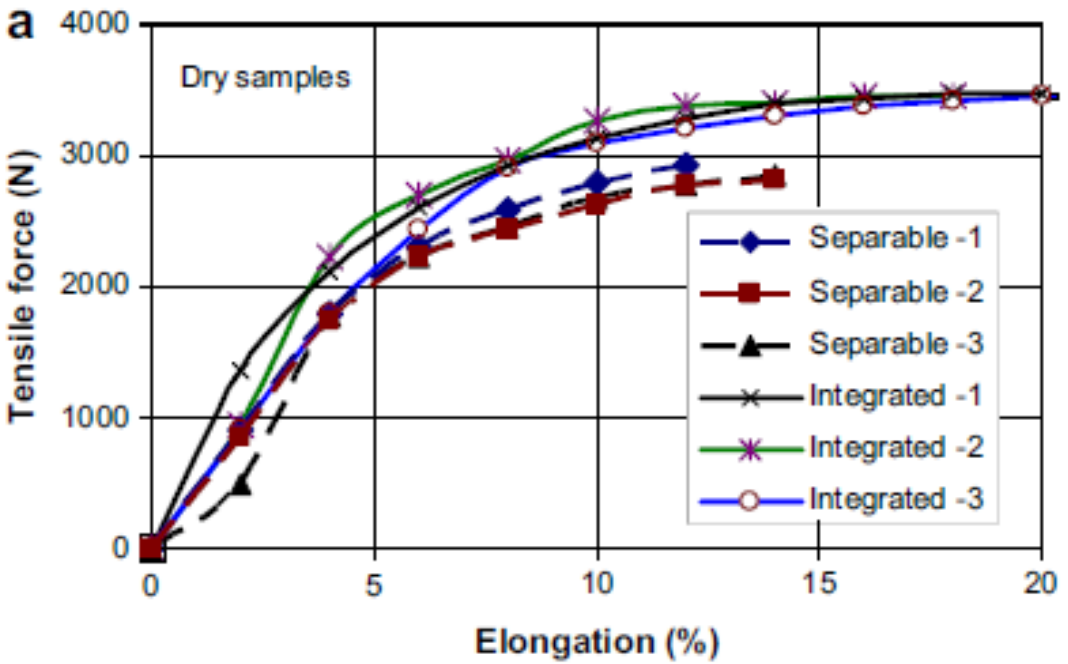
- Reduces indentation thus increase discharge capacity by >30%;
- Higher tensile strength as the core and filter are working together;
- Higher resistance to clogging;
- Save filter material;
- Easier production.






**Discharge capacity increases by 38 to 49%**

**Both tensile strength & elongation at failure has increased 20% & 50%**

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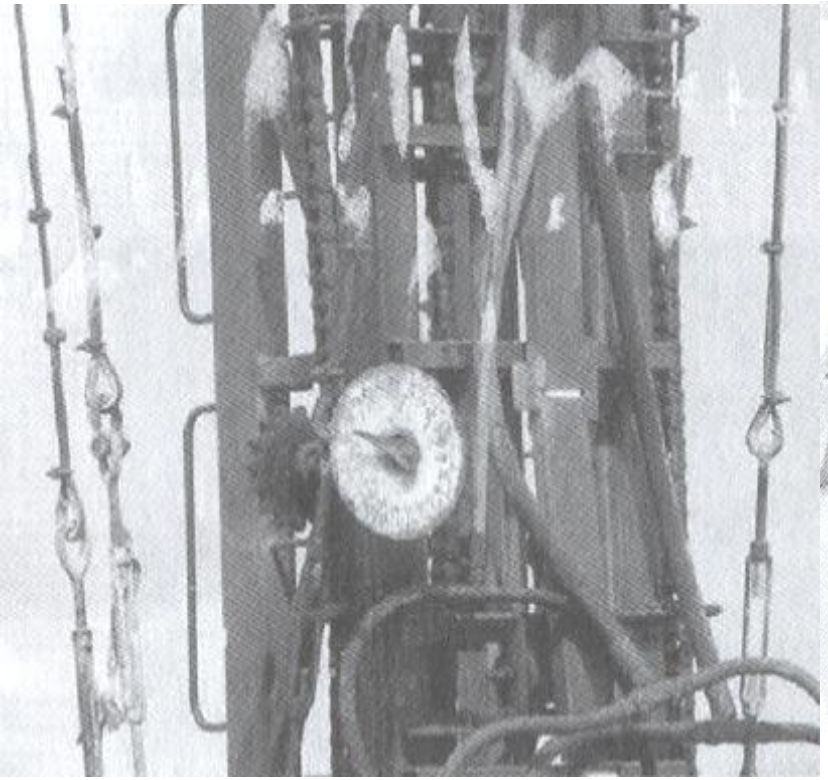
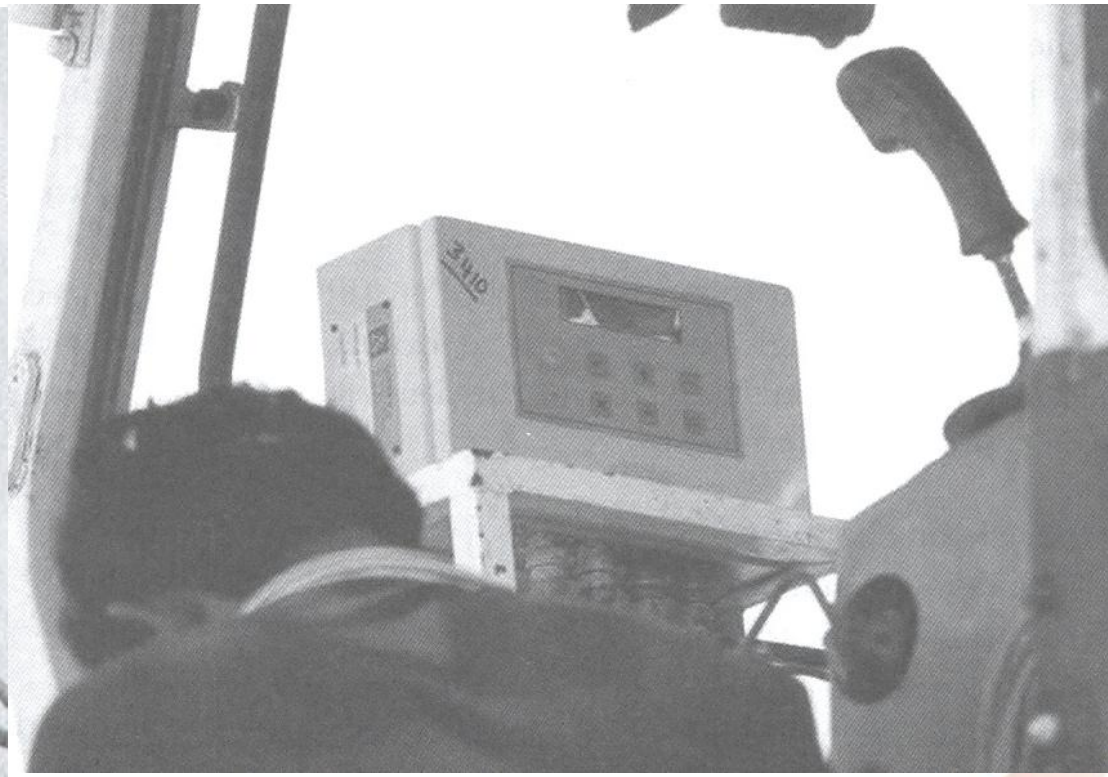
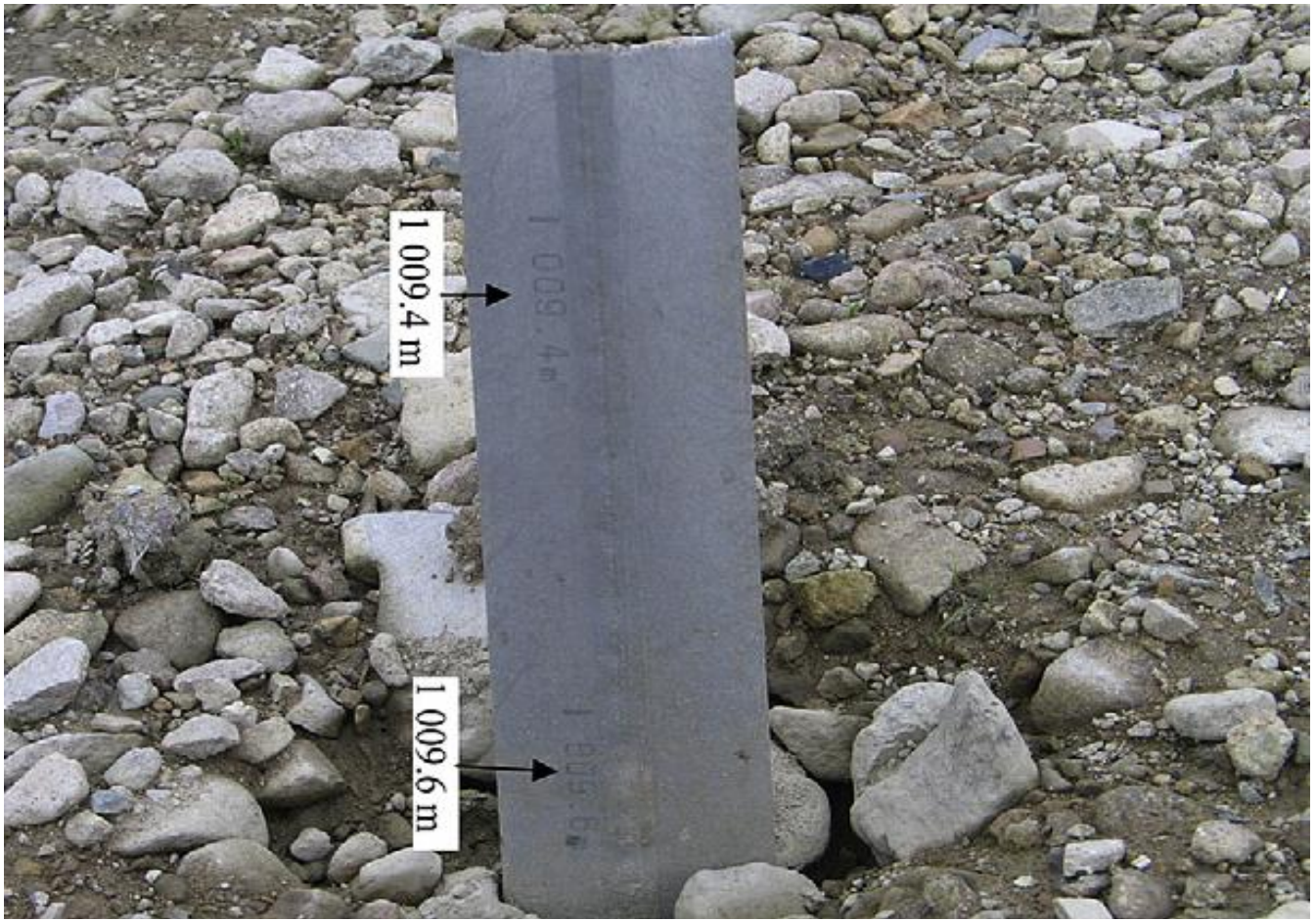
# PVD THAT ALLOWS INSTALLATION DEPTH TO BE MEASURED DIRECTLY

# Existing Methods: Counters to Record Installation Depth





# Solution 1 – print scale



# Solution 2 – use two wires

# Solution 3 – use one wire


Devices to measure the length of the drain

# Conclusions

- Quality control tests must be carried out for PVDs as these are not only construction but also design requirements – the discharge capacity of PVD has to be large enough for well resistance to be ignored. It is particularly the case for vacuum preloading. PVDs need to have the required tensile strength as well as AOS and permeability for the filter.
- Some simple QC tests that can be carried out in a site lab using simple soil testing equipment are introduced.
- Two new types of PVDs are introduced. The Integrated PVD increases the discharge capacity and tensile strength by >30% given the same production costs. PVDs can also be designed to measure directly the installation depth.

Chu, J., Bo, M. W., and Choa, V. (2004). “Practical considerations for using vertical drains in soil improvement projects.” *Geotextiles and Geomembranes*, Vol. 22, 101-117.

Liu, H.L. and Chu, J. (2009). “A new type of prefabricated vertical drain with improved properties.” *Geotextiles and Geomembranes*, Vol. 27, No. 2, 152-155.

Liu, H.L., Chu, J. and Ren, Z.Y. (2009). “New methods for measuring the installation depth of prefabricated vertical drains.” Geotextiles and Geomembranes, Vol. 27, No. 6, 493-496.