CONSOLIDATION AND DRYING PROPERTIES OF SEWAGE SLUDGE

Brendan C. O'Kelly

Trinity College Dublin

Geotechnical Society of Ireland Seminar

14 March 2005

OVERVIEW:

- Physical properties of sewage sludge
  - effects of level of biodegradation
- Air-drying and material density
- Compressibility and consolidation properties
  - liquid slurry and dried compacted sludge material
  - biologically active and stabilised material

QUANTIFYING AMOUNT OF PORE WATER

Geotechnical literature**:

Water content **w**, mass of pore water to mass of dry solid particles, as %

Water treatment literature:

Solids content **SC**, mass of dry solid particles to bulk sludge mass, as %

$$SC = \frac{100}{1 + \left(\frac{w}{100} \right)} \qquad \text{(as \%)}$$

- TEST MATERIAL
  - Tullamore municipal wastewater treatment plant
  - Anaerobic, activated sludge digestion method
  - Treated material dewatered to w ≅ 720 % using belt filter press

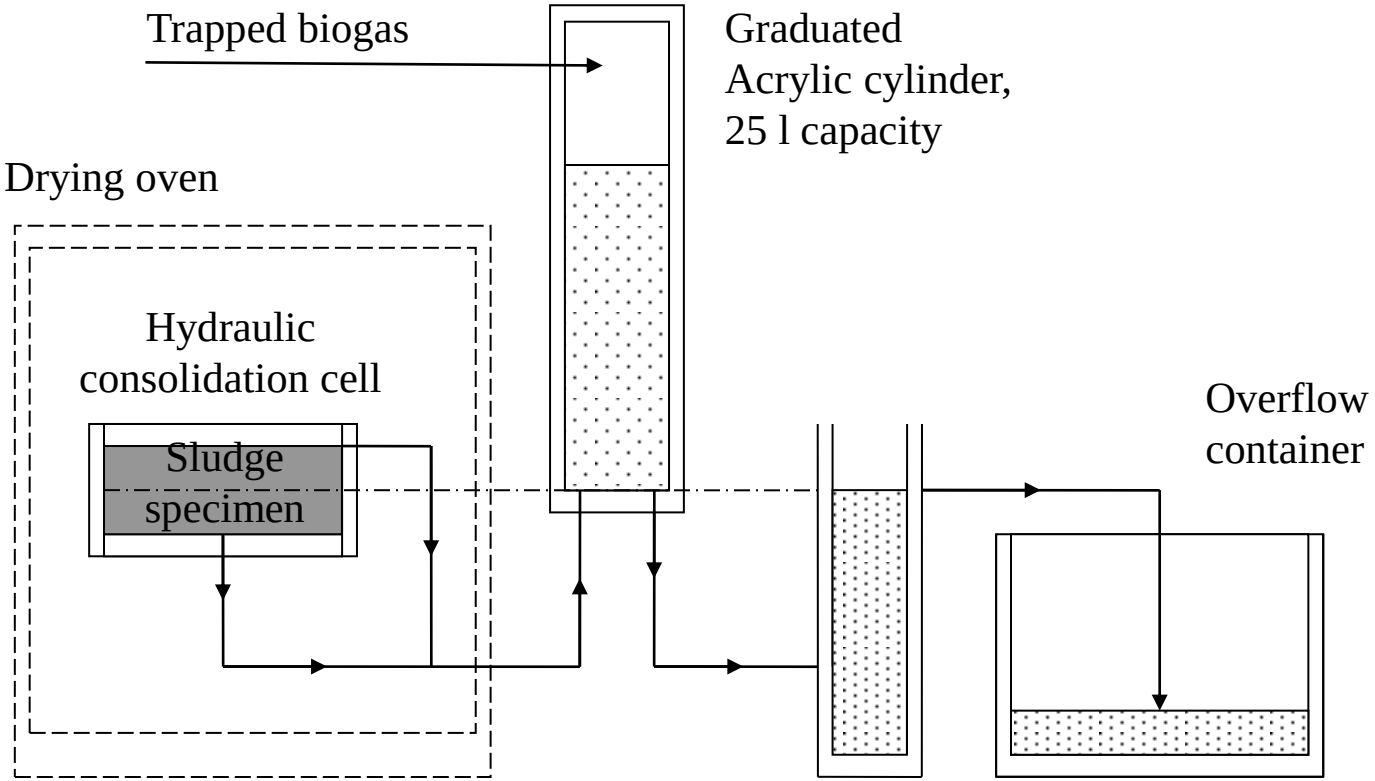
PHYSICAL PROPERTIES

Liquid limit	315 %
Plastic limit	55 %
Shinkage limit	10 %
Plasticity index	260 %
Specific gravity of solids	1.55
Ignition loss	70 %
Water content	720 %
Void ratio	11
Bulk unit weight	10.2 kN/m^3
Dry unit weigth	1.3 kN/m^3
pH	8.0

- Typical properties of slurry direct from wastewater plant
- Properties indicate sludge material was moderately degraded

PREPARATION OF MORE STRONGLY DEGRADED MATERIAL

i) Further biodegradation of slurry in laboratory at 35 ºC



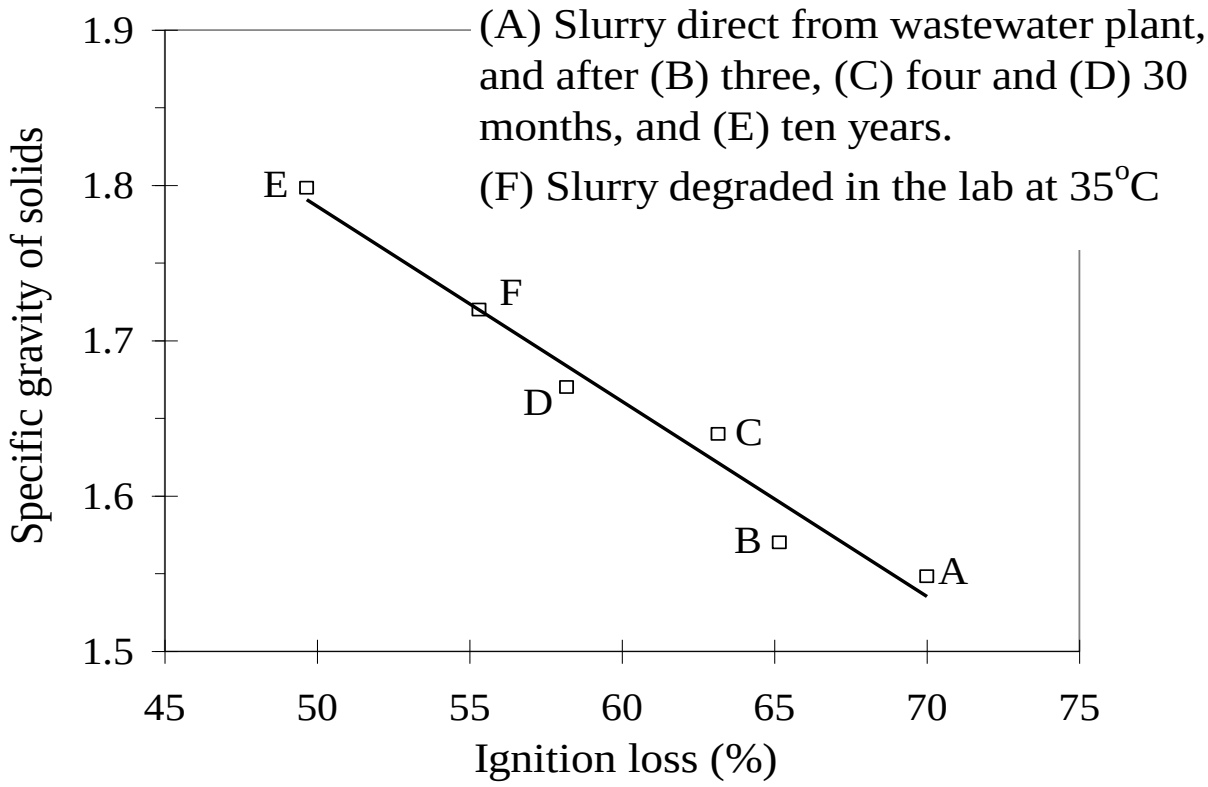
STABILIZATION (optional): slurry pasteurized by heating at 80^{o}C for 3 hours

ii) Sludge also stored outdoors in drums and allowed degrade naturally over ten-year period

PHYSICAL PROPERTIES AND STATE OF BIODEGRADATION

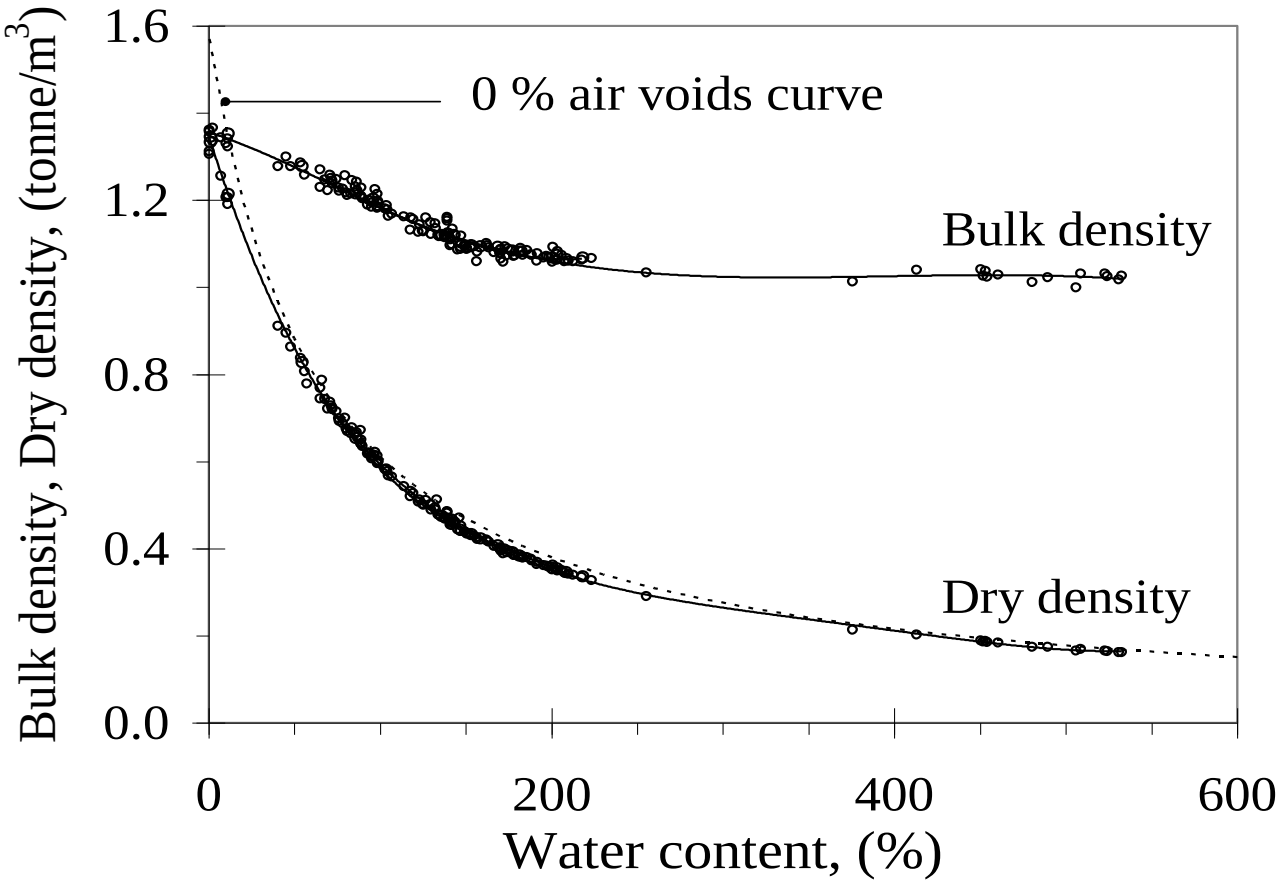
Ignition loss

- (% dry mass)
- indirect measure of organic content
- assess state of degradation



AIR-DRYING AND DENSITY

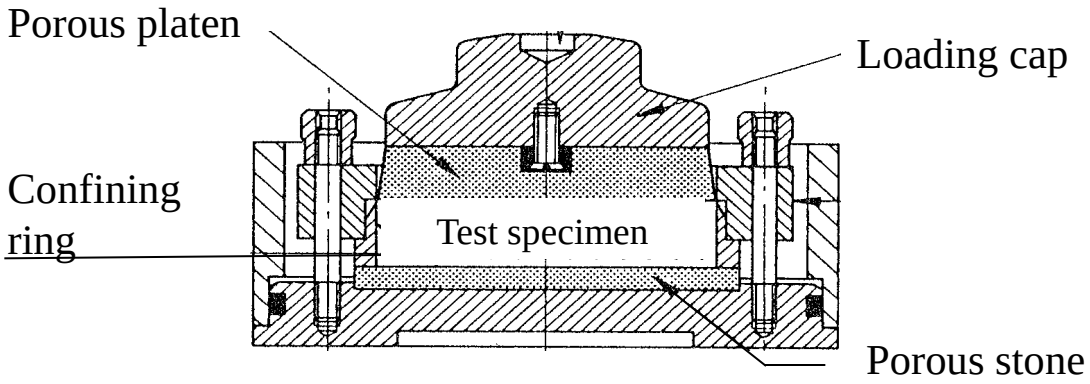
- Sludge material dried slowly outdoors



COMPRESSIBILITY AND CONSOLIDATION PROPERTIES

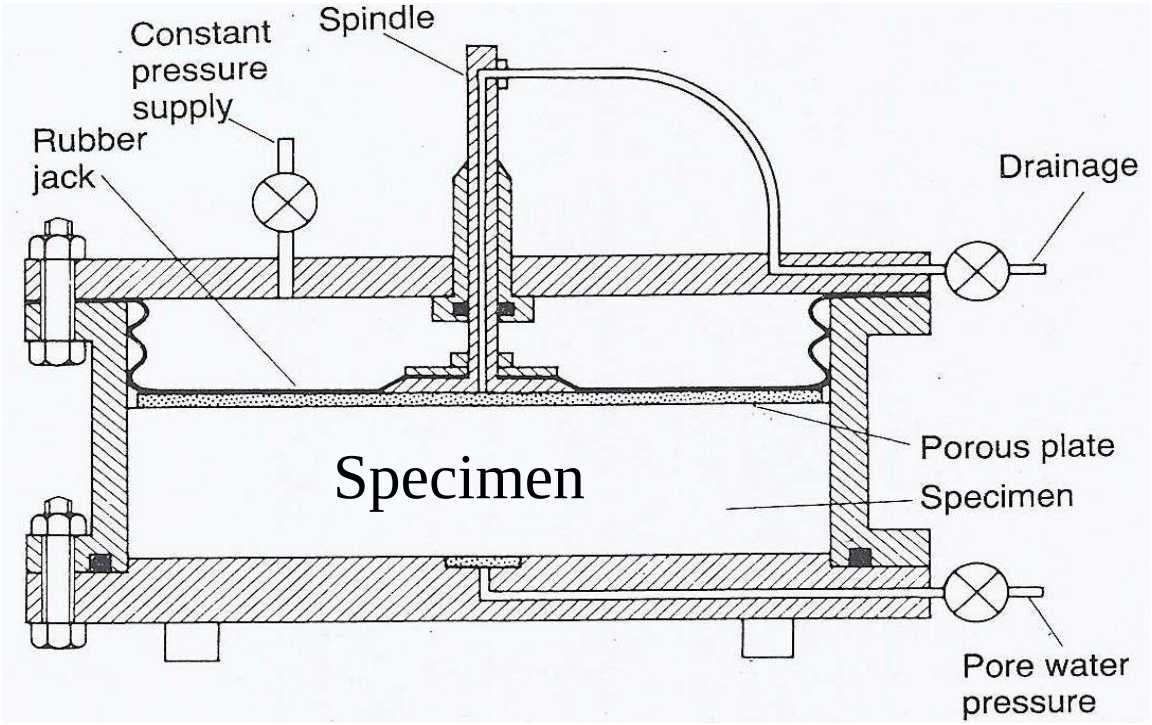
- TEST APPARATUS:

i) <u>Oedometer consolidation cell</u>



- Test specimen dimensions:
  - 76mm dia. x 19mm high, to 100mm dia. x 40mm high
  - Consolidation pressures increasing from 3 kPa for slurry, up to 400 kPa for dried compacted sludge material

ii) Hydraulic consolidation cell

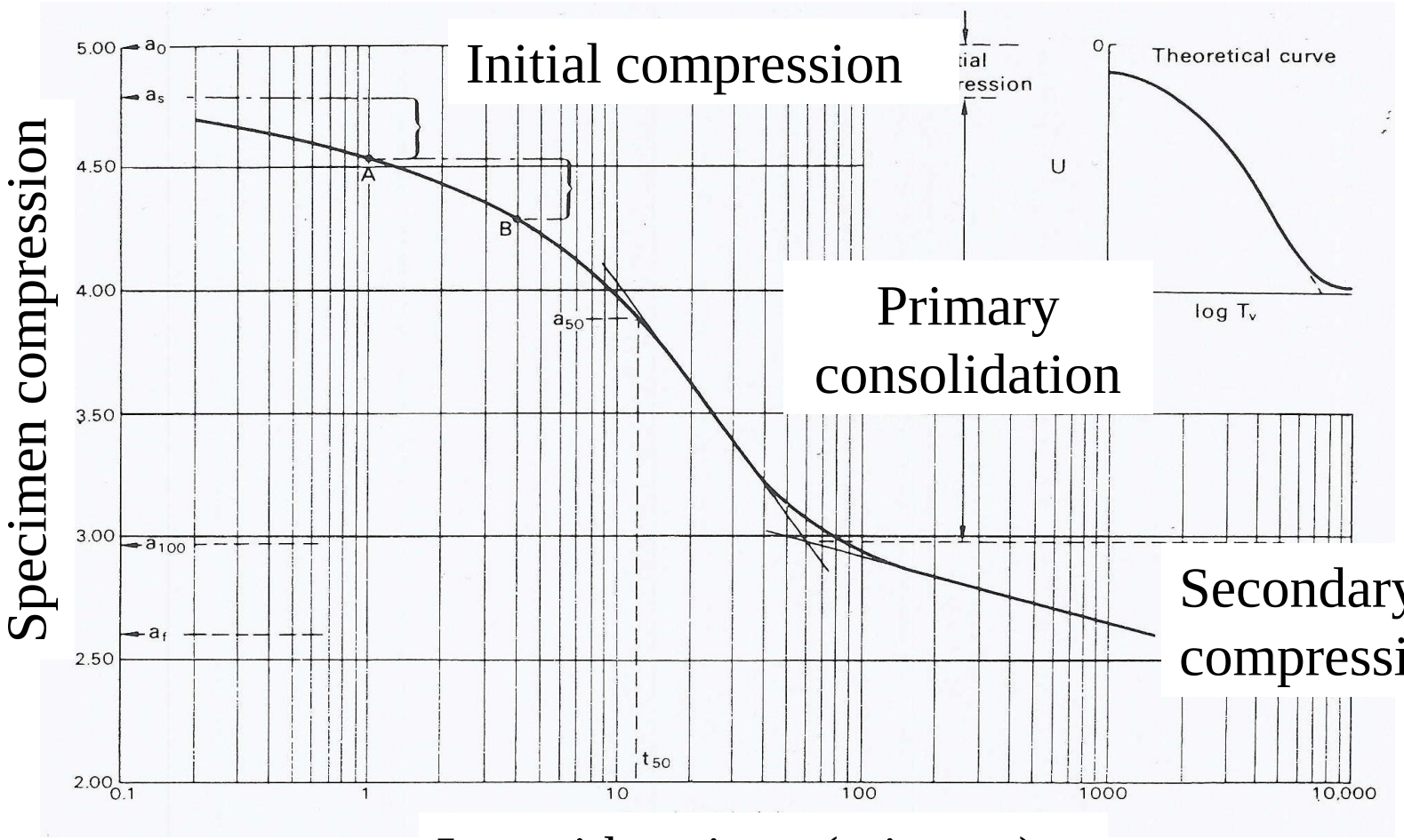


- Test specimen dimensions:

  250mm diameter x 50mm high

  Effective confining pressures of 100 to 300 kPa

CONVENTIONAL ONE-DIMENSIONAL CONSOLIDATION CURVE

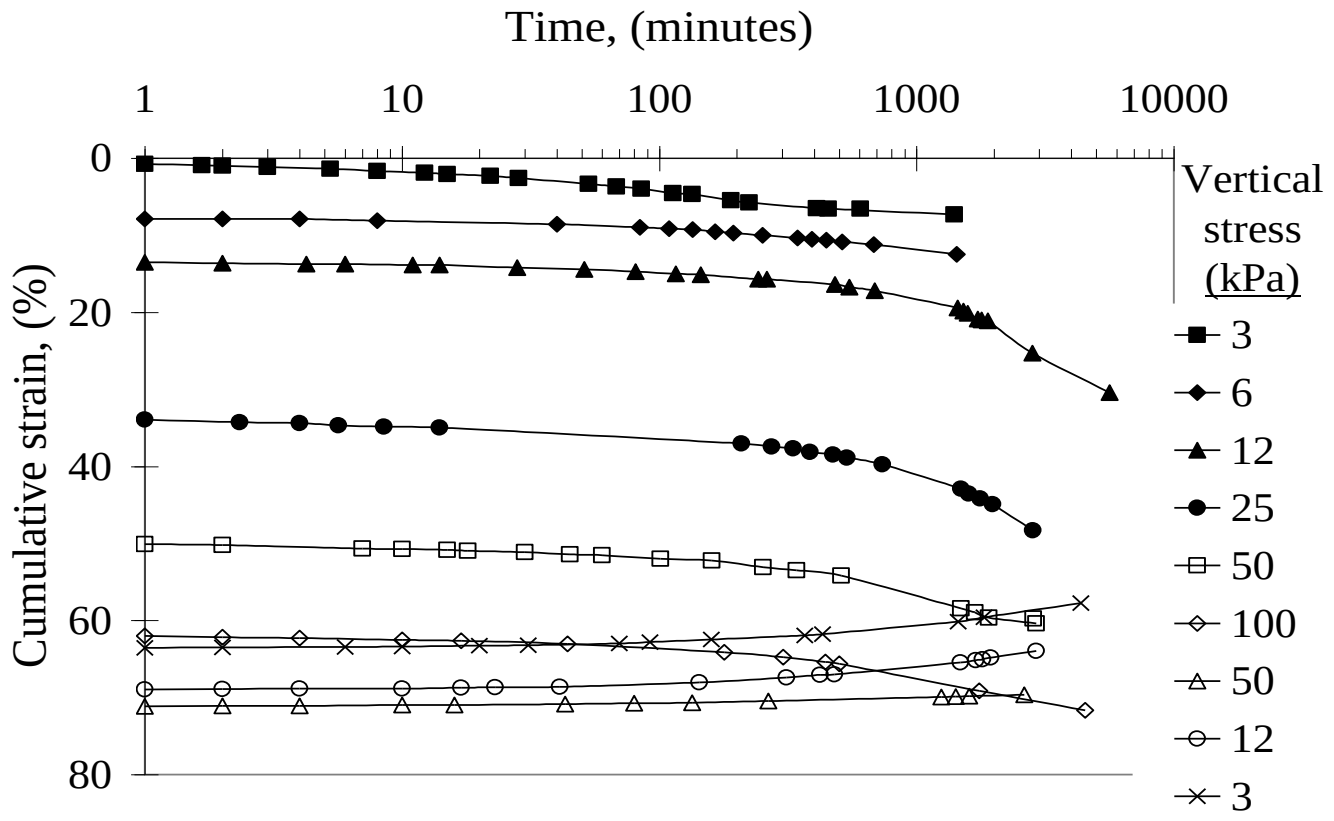


TEST RESULTS

Moderately degraded sludge material:

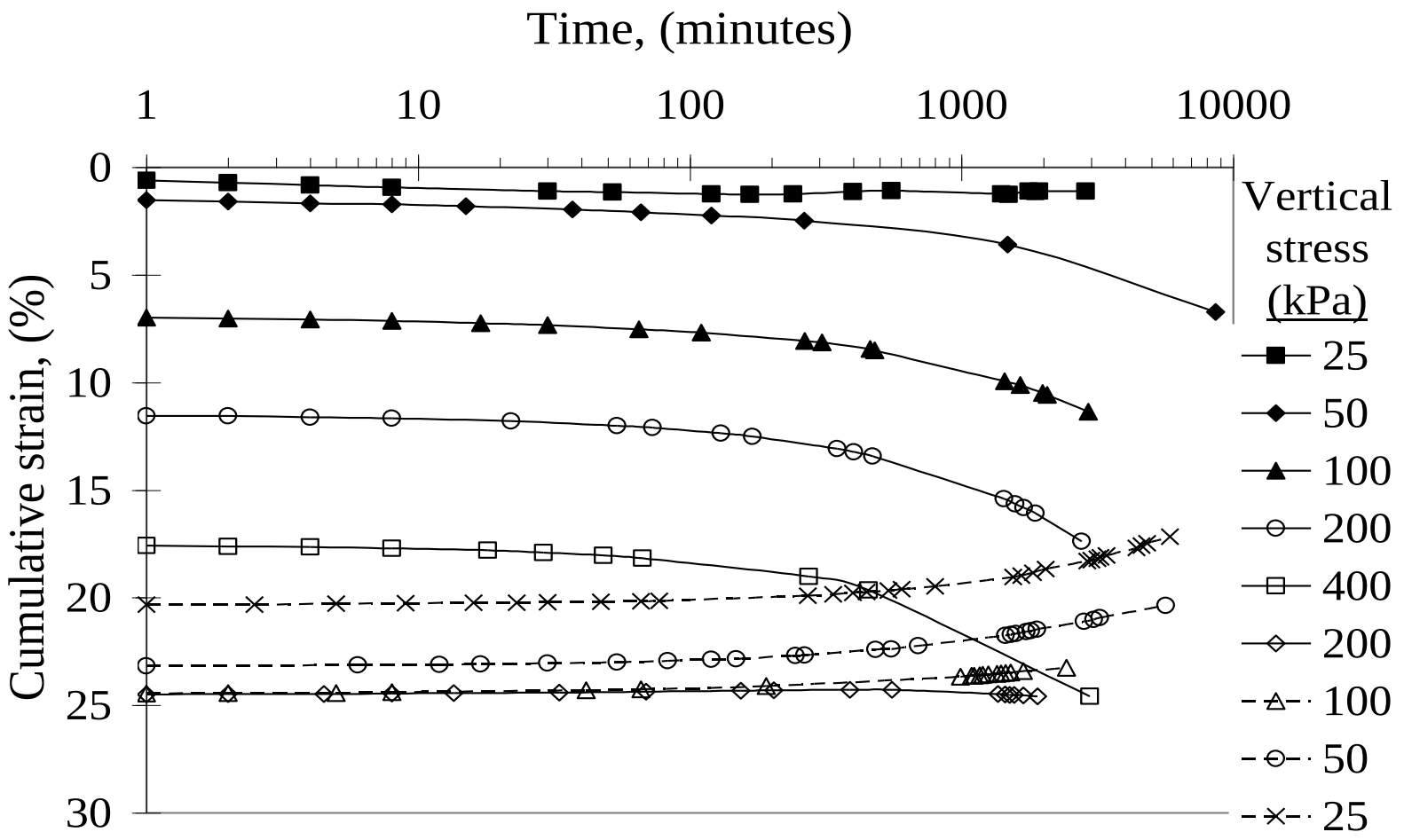
- biologically active

  i) Slurry direct from treatment plant (w ≅ 720 %)

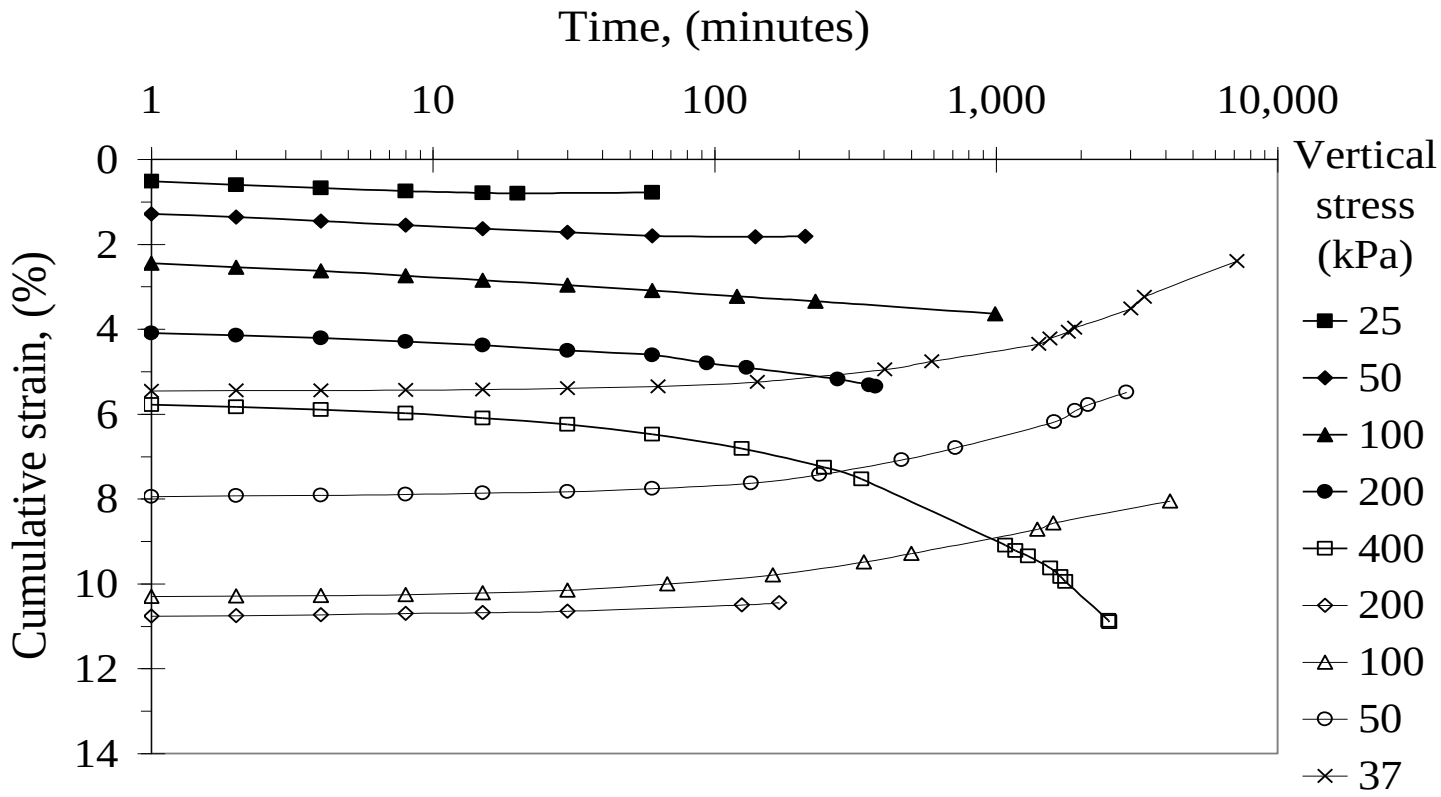


Dried, standard Proctor compacted sludge material

ii) Wet of optimum water content, w≅130%



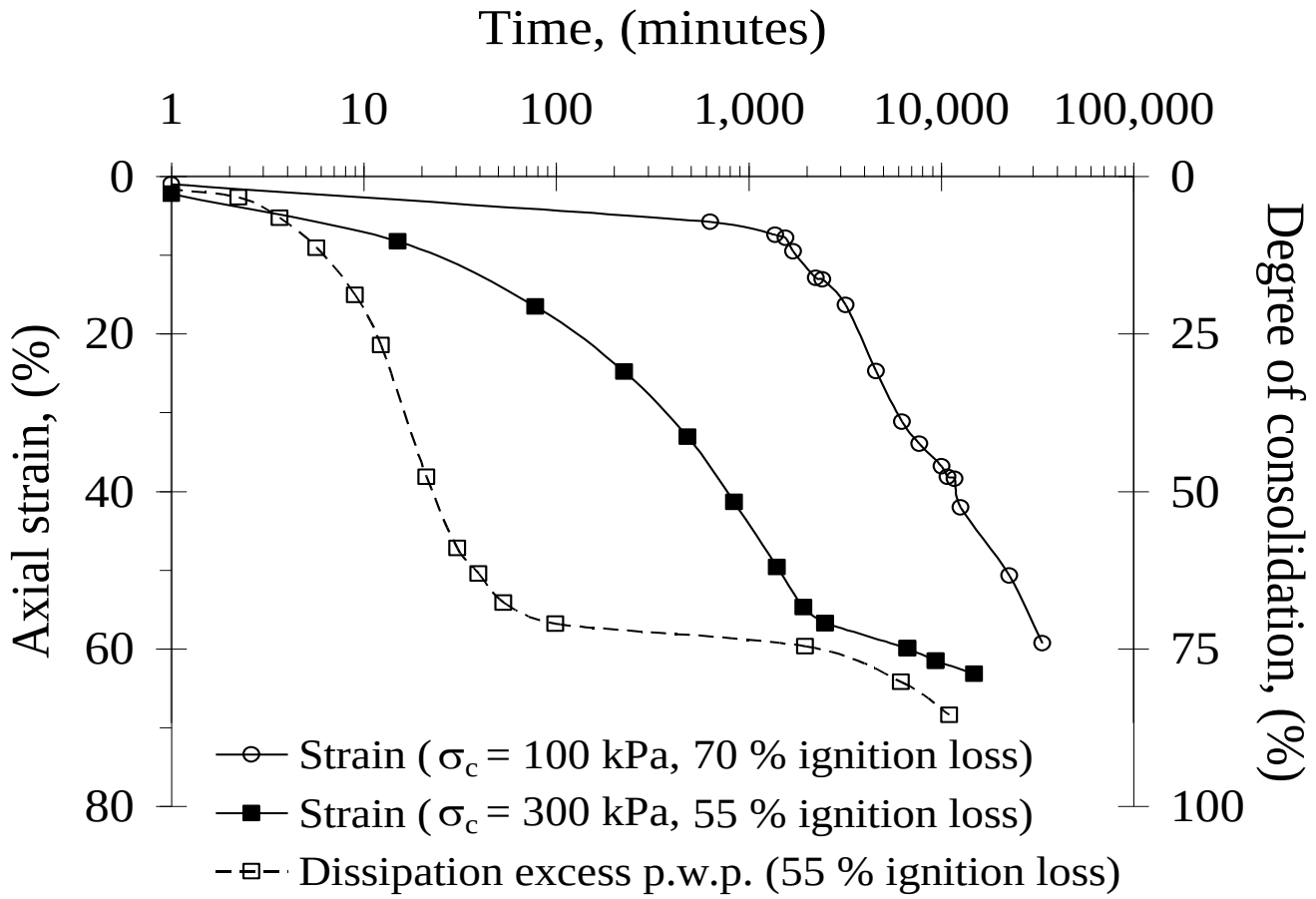
iii) Compacted at optimum water content, w ≅ 100%



Comparison:

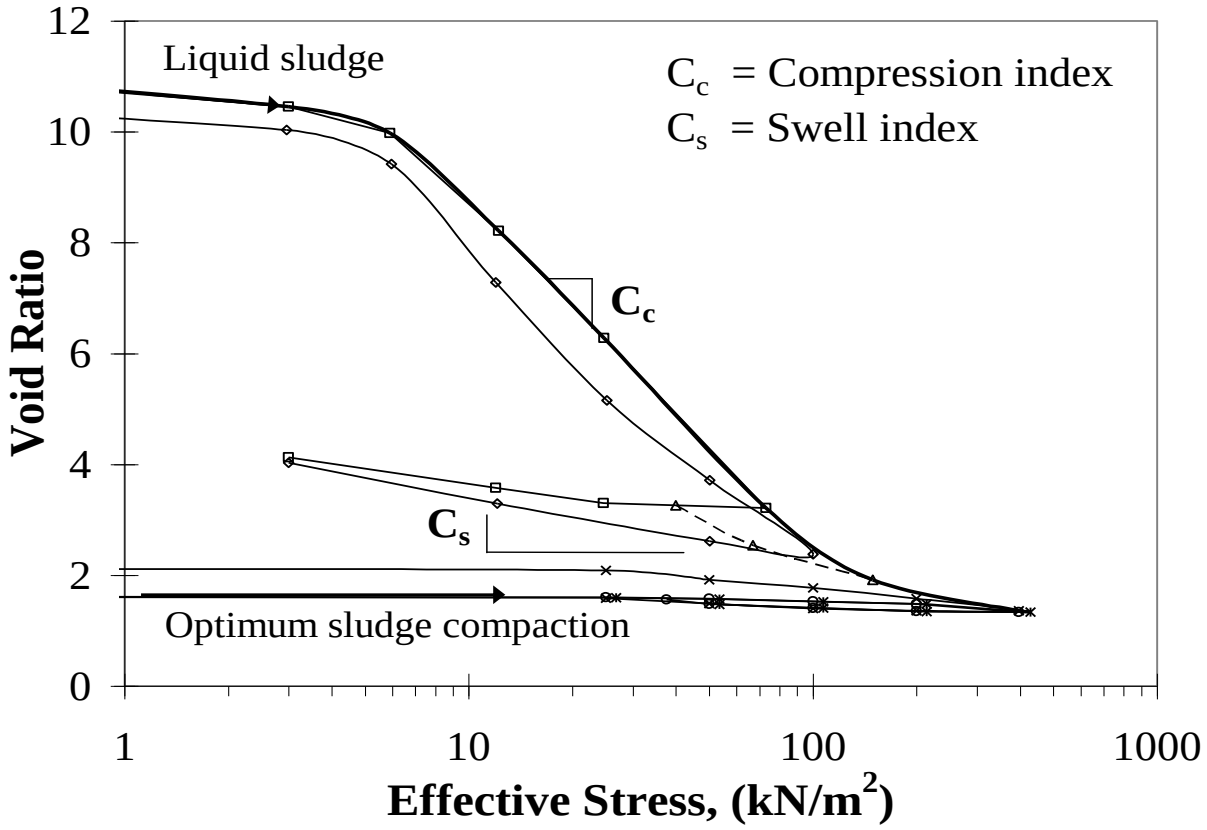
Moderately and strongly degraded sludge material, biologically stabilised

iv) Slurry direct from treatment plant (w ≅ 720 %)



SUMMARY OF COMPRESSIBILITY DATA

Void ratio, volume of void space to volume of solid particles



Calculate amount of consolidation settlement in sludge monofill

CONSOLIDATION

- Primary consolidation:
  - compression associated with dissipation of excess porewater pressure
- Secondary compression:
  - indefinite creep, and in case of sludge, significant contribution due to ongoing degradation
- Primary consolidation occurred fairly rapidly but constituted only minor part of overall strain response

- coefficient of permeability k, for moderately degraded slurry of the order of 10^{-9} m/s
  - greater permeability for higher states of biodegradation
  - but permeability decreases significantly with increasing applied stress

- Secondary compression by far dominant mechanism causing settlement

SUMMARY

- Physical and mechanical properties affected by level of degradation

  – Specific gravity, density and permeability increase with increasing level of biodegradation
  – Strongly biodegraded, stabilised sludge material consolidates more readily
  – bioegradation continues many years after treatment at waterwater plant

- Sludge material dried slowly outdoors

- Sludge material practically impermeable,
  $k<10^{-9}$ m/s

- Settlement of landfilled material occurs very slowly, and occurs mainly due to creep and ongoing biodegradation

THANK YOU