

CONSOLIDATION AND DRYING PROPERTIES OF SEWAGE SLUDGE

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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 POREWATER

Geotechnical literature**:

Water content w , mass of porewater to mass of dry solid particles, as %

Water treatment literature:

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

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

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

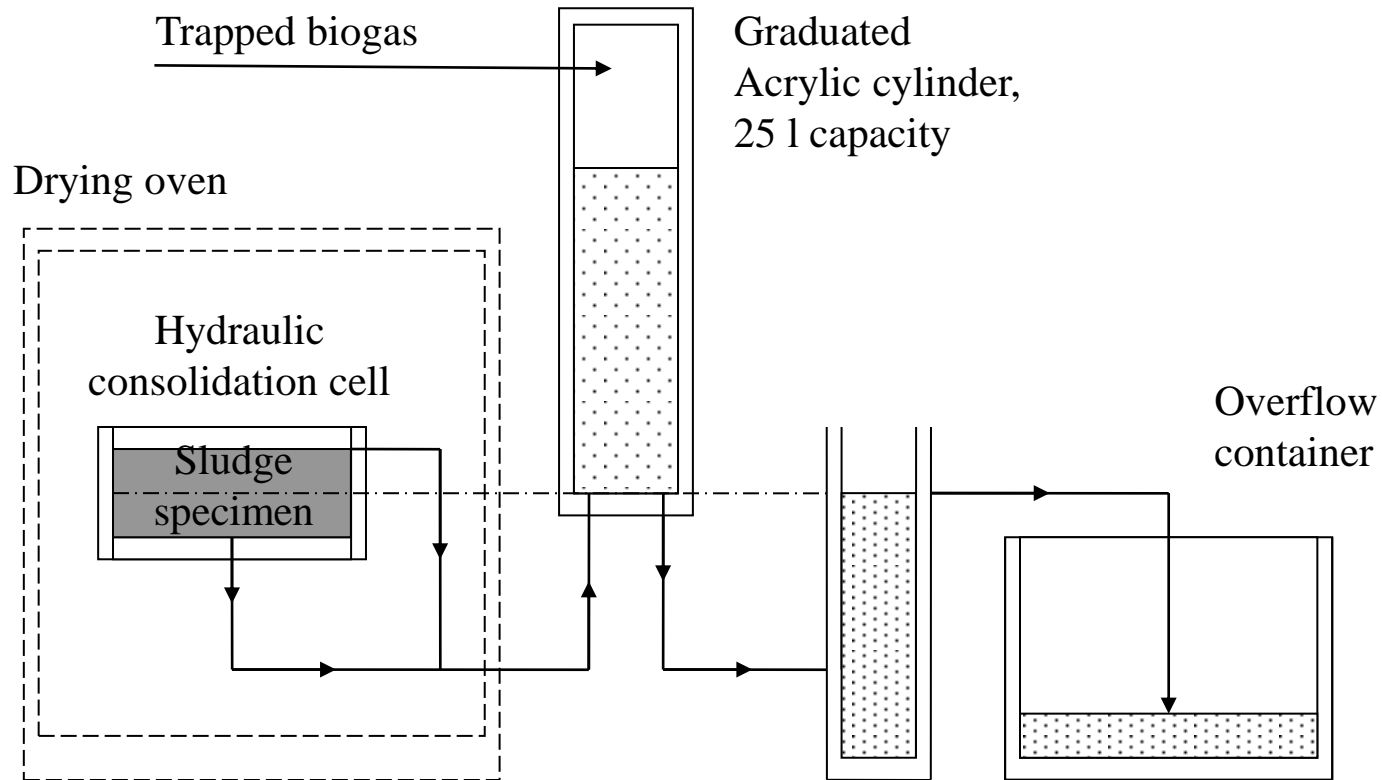
PHYSICAL PROPERTIES

Liquid limit	315 %
Plastic limit	55 %
Shrinkage 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 weight	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 °C



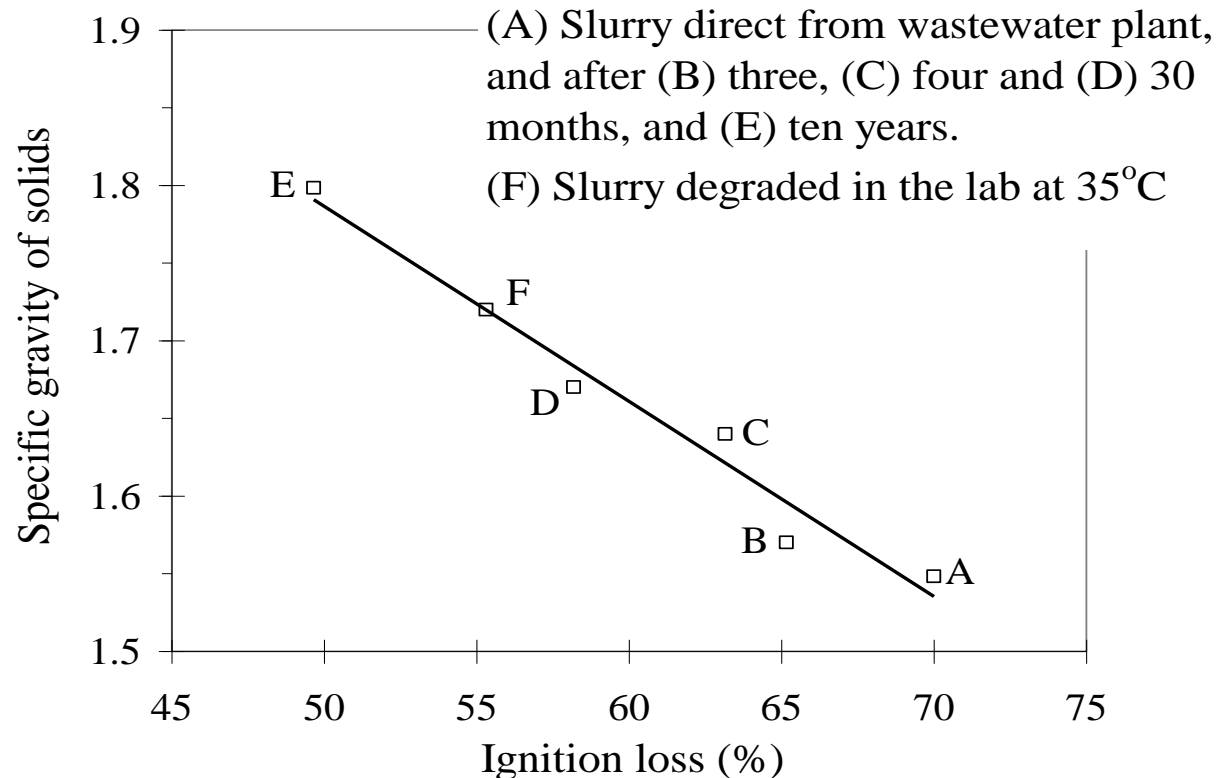
STABILIZATION (optional): slurry pasteurized by heating at 80°C for 3 hours

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

PHYSICAL PROPERTIES AND STATE OF BIODEGRADATION

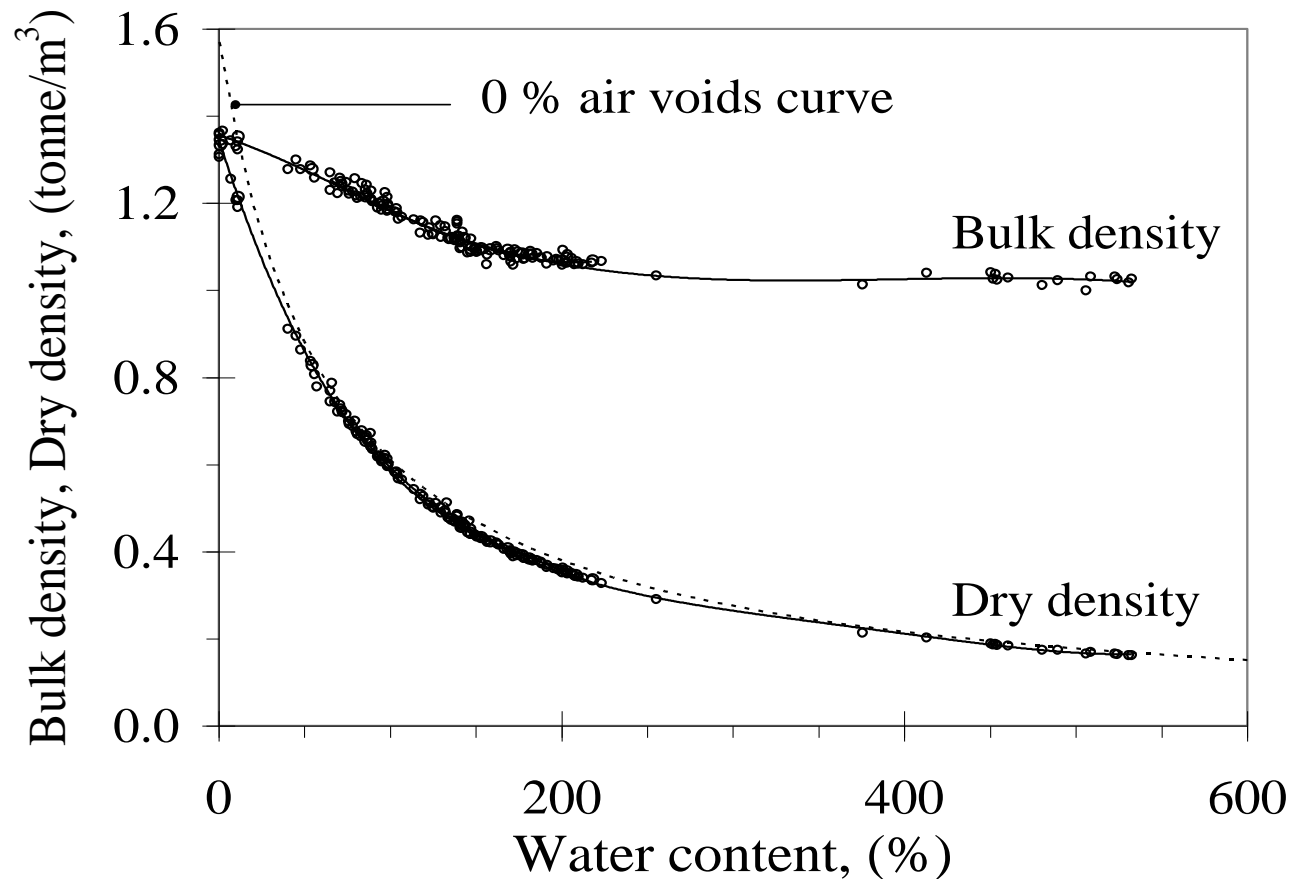
Ignition loss

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



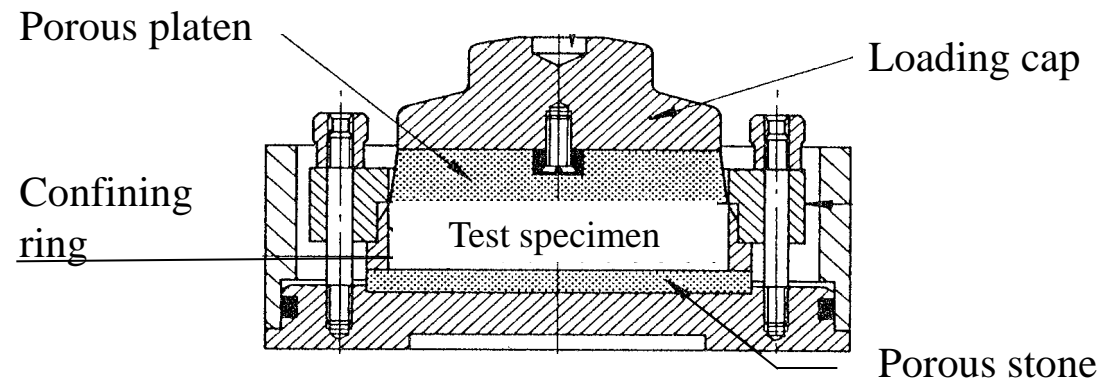
AIR-DRYING AND MATERIAL DENSITY

- Sludge material dried slowly outdoors



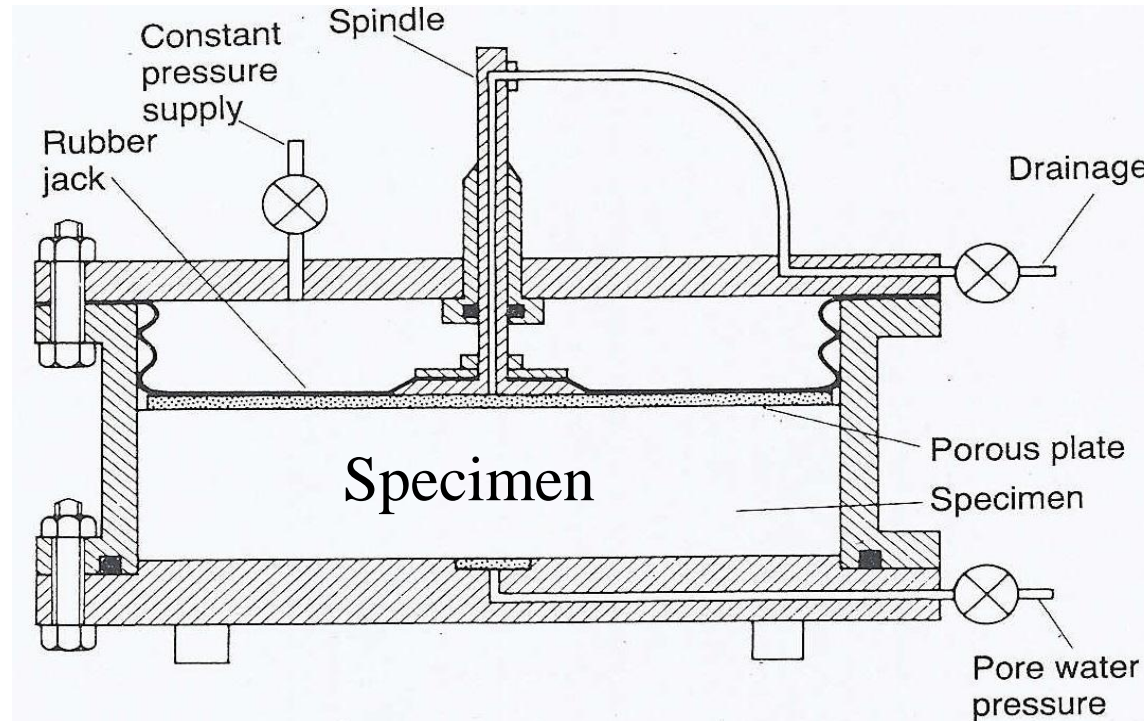
COMPRESSIBILITY AND CONSOLIDATION PROPERTIES

- TEST APPARATUS:
 - i) Oedometer consolidation cell



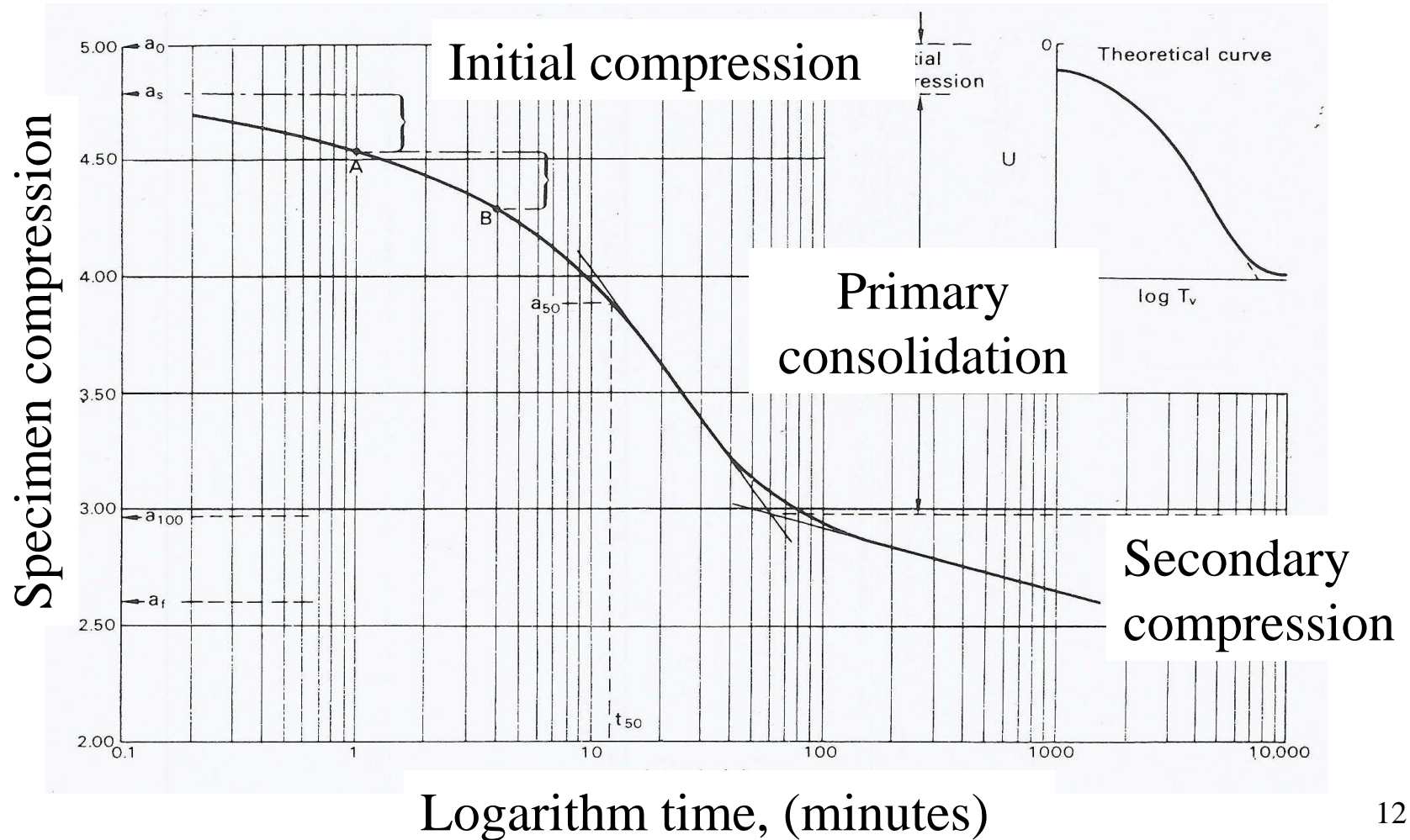
- Test specimen dimensions:
 - 76mm dia. x 19mm high, to 100mm dia. x 40mm high
 - Consolidation pressures increasing from 3 kPa for slurry, up to 400 kPa for dried compacted sludge material

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

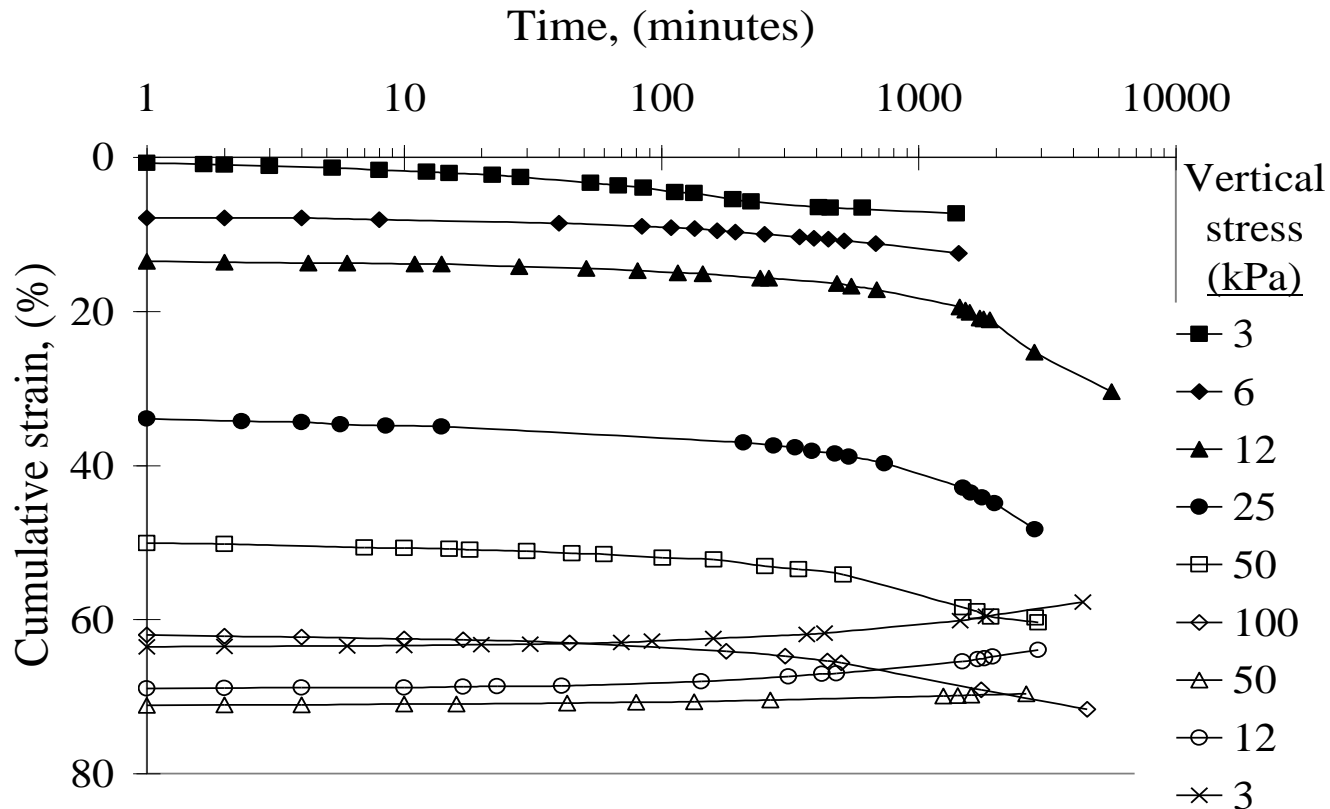


TEST RESULTS

Moderately degraded sludge material:

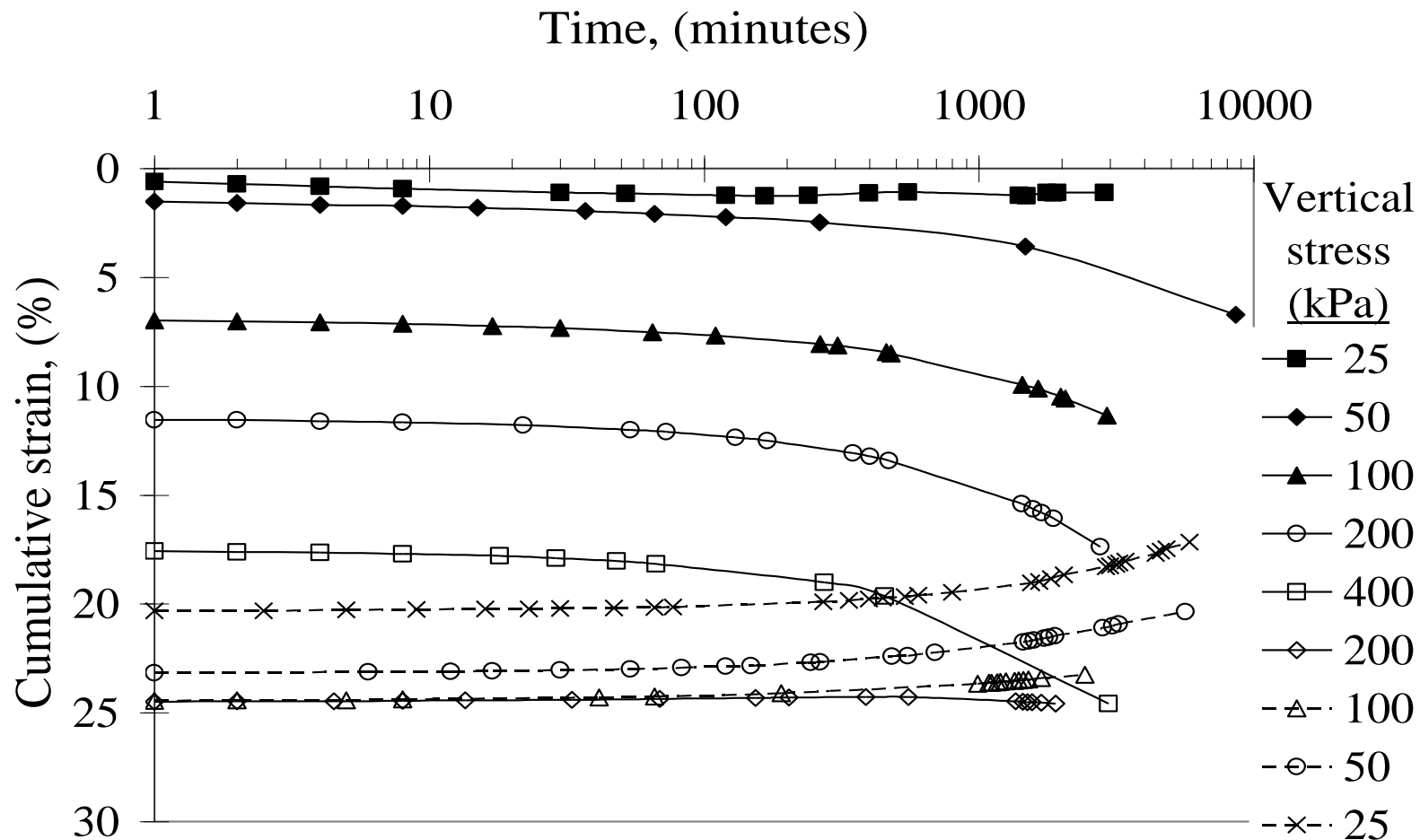
- biologically active

i) Slurry direct from treatment plant ($w \cong 720\%$)

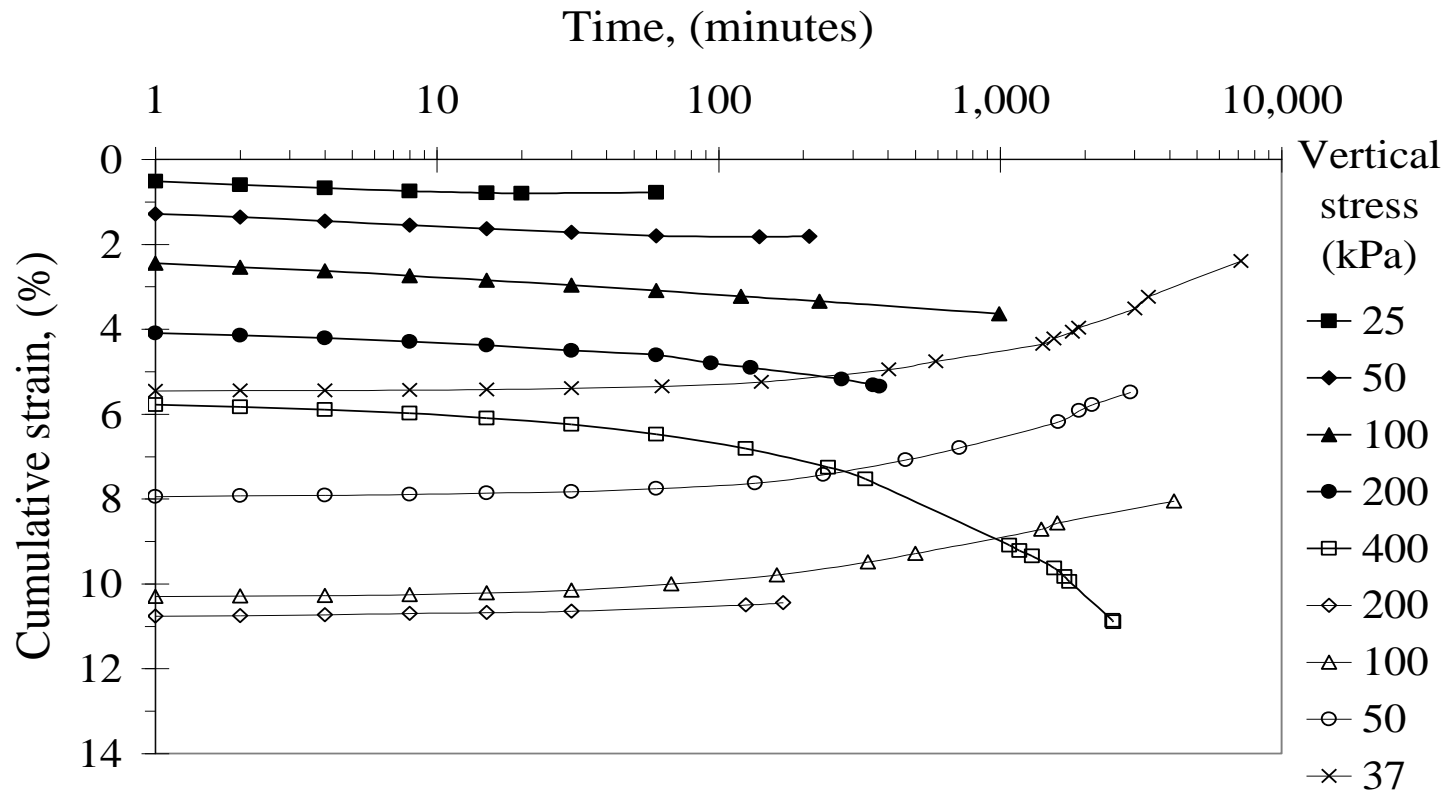


Dried, standard Proctor compacted sludge material

ii) Wet of optimum water content, $w \cong 130\%$



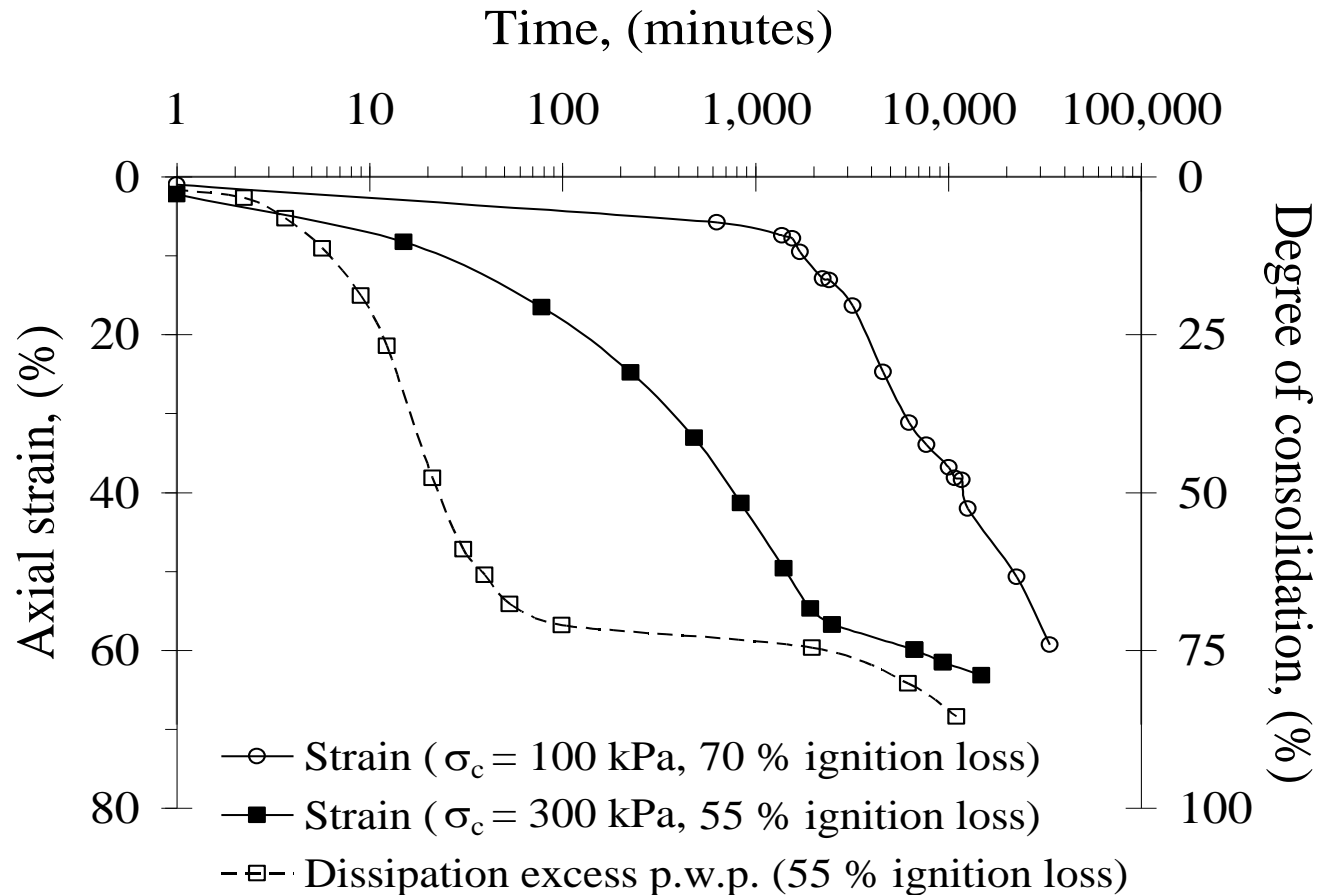
iii) Compacted at optimum water content, $w \cong 100\%$



Comparison:

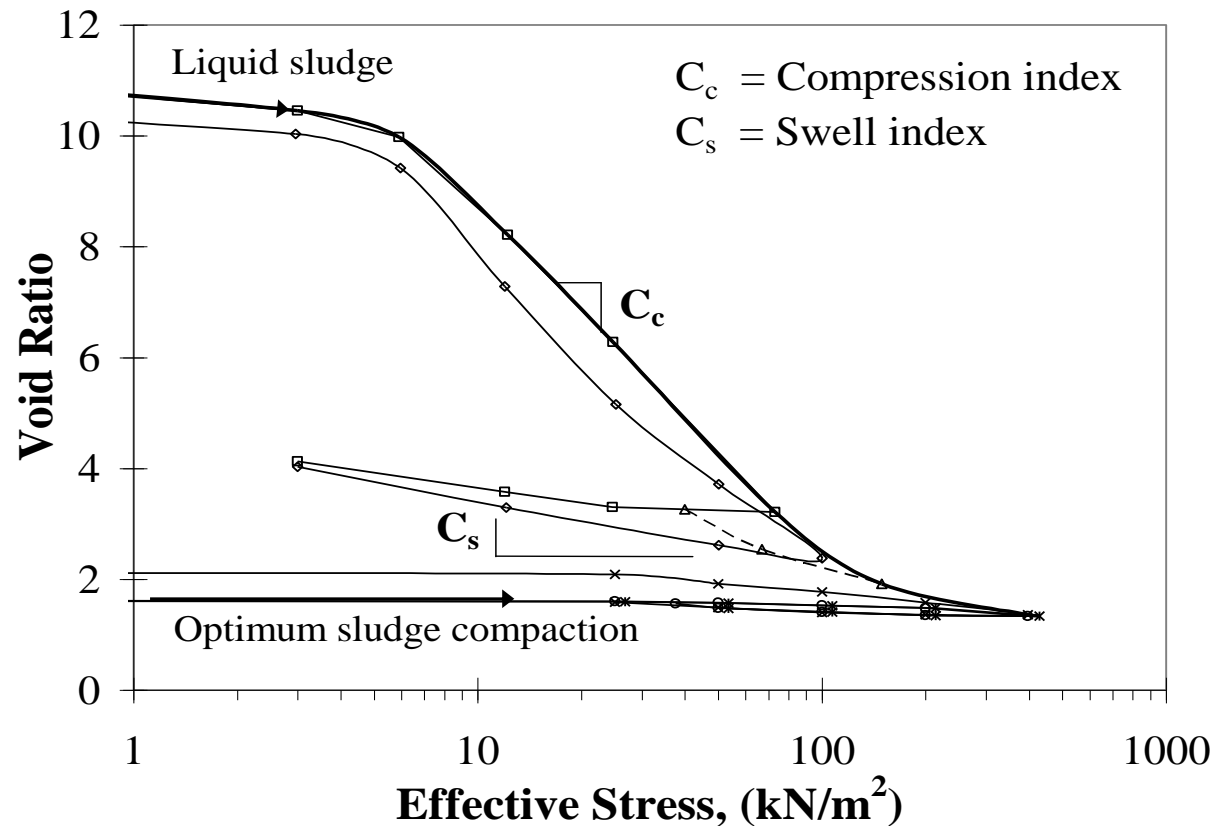
Moderately and strongly degraded sludge material, biologically stabilised

iv) Slurry direct from treatment plant ($w \cong 720\%$)



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 degradation
 - 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 degradation
 - Strongly degraded, stabilised sludge material consolidates more readily
 - Degradation 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