Shear Strength of Municipal Solid Waste

M. A. Gabr, M. S. Hossain, and M. A. Barlaz

Department of Civil Engineering
North Carolina State University
Raleigh, NC 27695

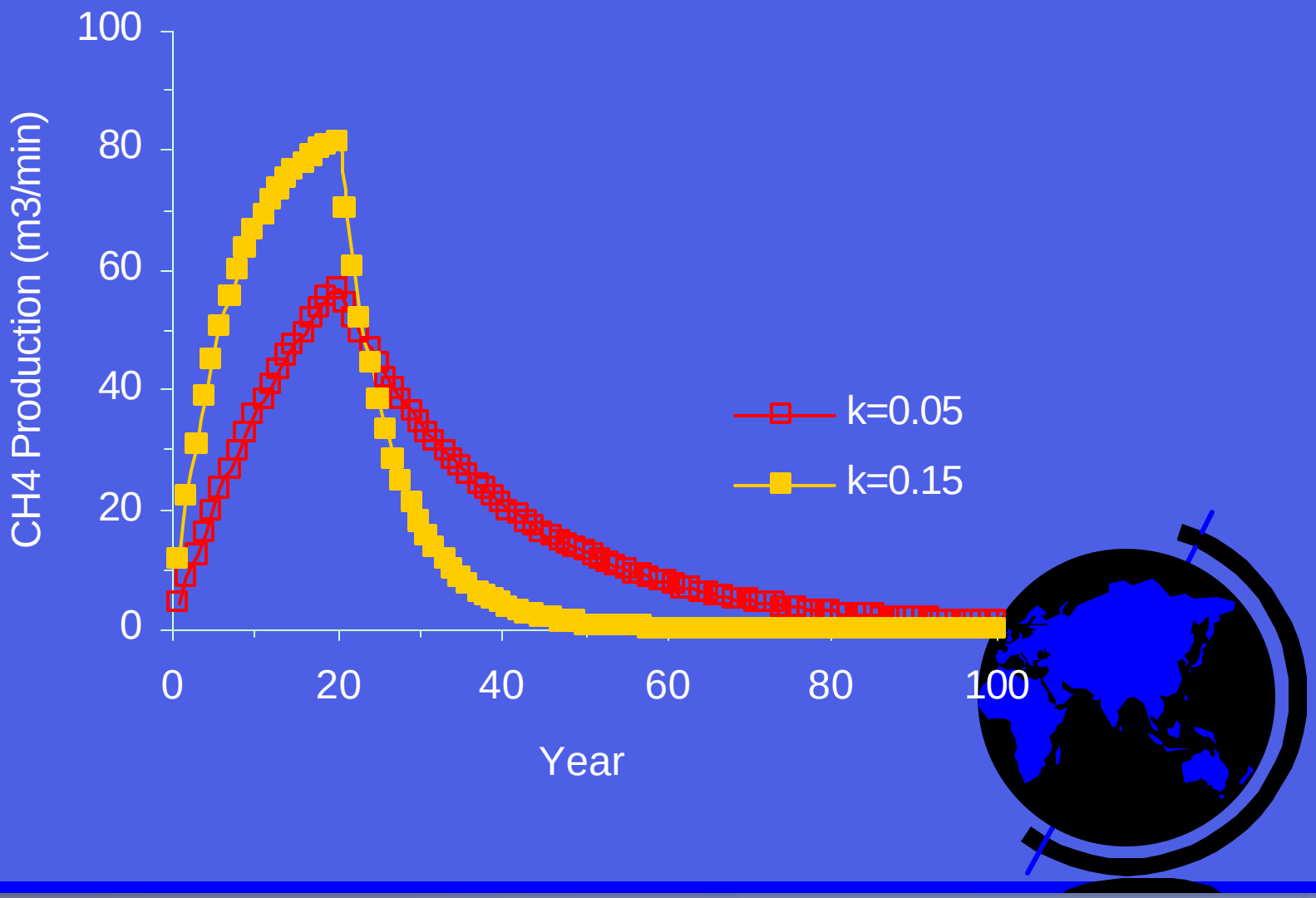
Problem Statement

- Explanation of Measured Shear Stress-Displacement
- Impact of Degradation on Strength Properties

Waste Decomposition Phases (Barlaz et al 1989)

- Aerobic Phase
- Anaerobic Acid Phase
- Accelerated Methane Phase
- Decelerated Methane Phase

Waste Decomposition Phases



Shear Strength of MSW

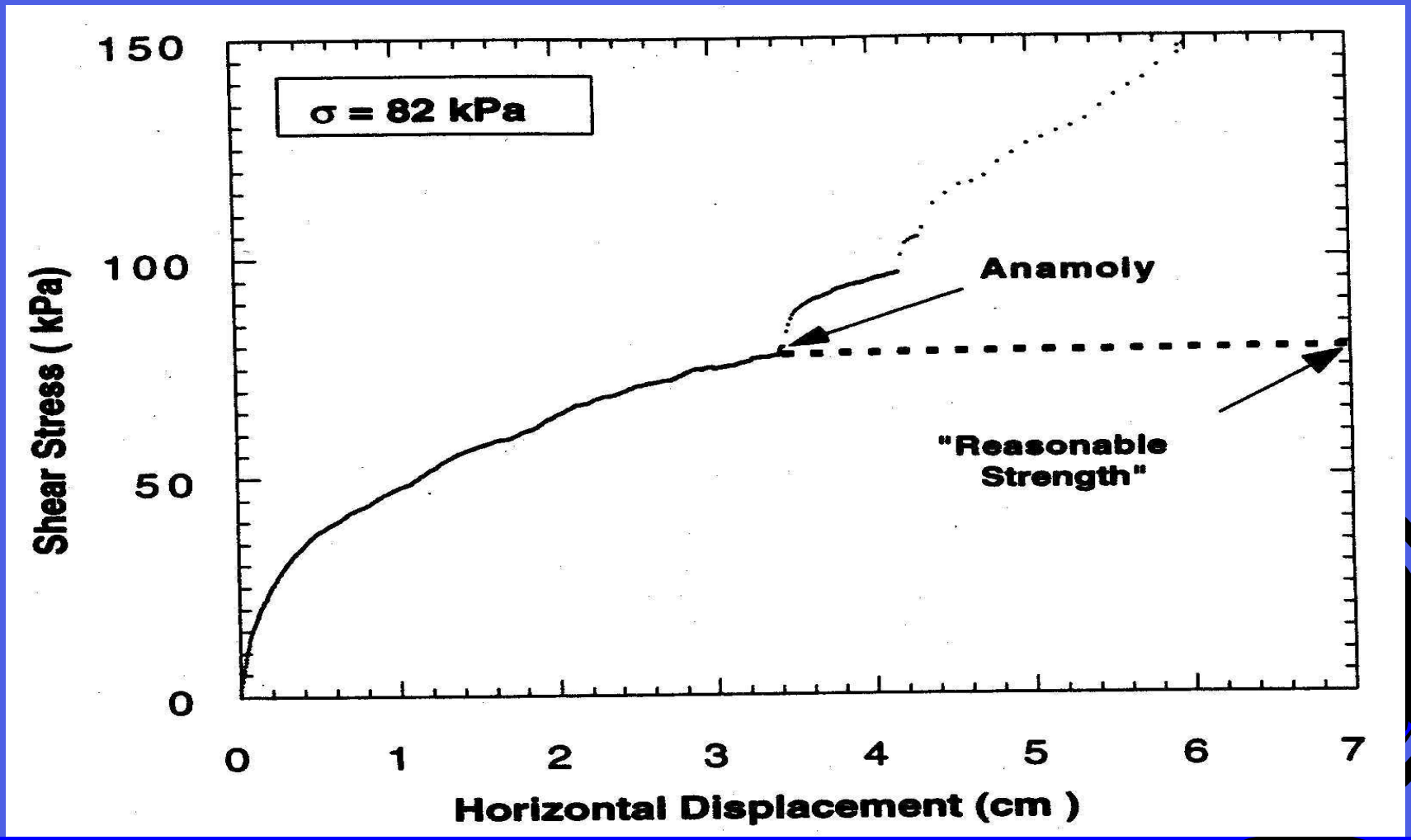
- Landva and Clark (1986) - old refuse
  - Friction angle =38^{o} to 42^{o}
  - Cohesion = 16 to 19 kPa
  - 1 Year later :Friction angle = 33^{o}
    Cohesion = 16 kPa

- Howland and Landva (1992) - 10 to 15 years old refuse
  - Friction angle =33^{o}
  - Cohesion = 17 kPa

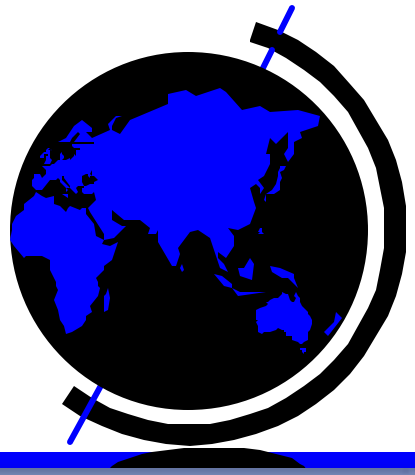
Shear Strength of MSW

- Gabr and Valero (1995) - 10 to 15 years old refuse
  - Friction angle =20^{o} to 39^{o}
  - Cohesion = 28 kPa to 0
  - 15 % increase in moisture, 50% decrease in cohesion

Shear Strength (Edincliler et. al., 1996)

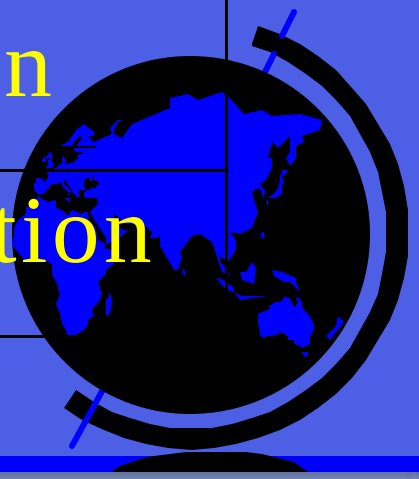


Sample Preparation



Generation of Waste Samples

Reactor Set	Test Condition
1	Leachate Recirculation and Neutralization
2	Leachate Recirculation



Reactor Operation and Monitoring (1)

- **Sample Collection**
- **Reactor Design and Loading**

Reactor Monitoring and Operation (2)

Reactor Operation and Monitoring (3)

- Incubation Conditions
- Data Collection
  - Gas Volume
  - Gas Composition
  - pH
  - Solid Analysis

Generated Samples

- Reactor-9 : Sampled after 24 days (Sample B1)

- Reactor-14 : Sampled after 53days (Sample B2)

Generated Samples

- Reactor-12 : Sampled after 78 days (Sample B3)

- Reactor-11 : Sampled after 127 days (Sample B4)

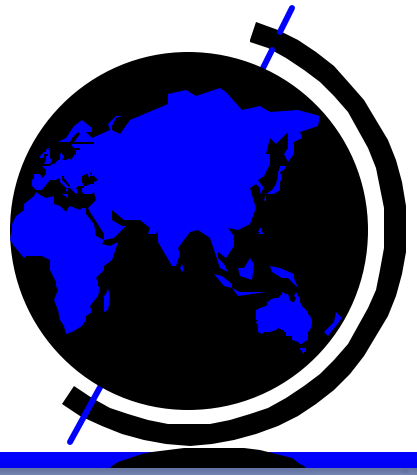
Experimental Program – Shear Strength Parameters

Sample No.	(C+H)/L	Direct Shear	Sample Description
1	1.29	3	Sample at the initial stages of decomposition
2	0.73	3	Sample at accelerated methane production Phase
3	0.38	3	Samples at decelerated methane production phase
4	0.25	3	Samples at stable methane production phase
5	Fresh Paper	3	Fresh shredded paper
6	Plastics	3	All material except plastics were removed from samples at (C+H)/L=0.38;
7	Degraded paper, organics and textiles	3	Plastics were removed from samples at (C+H)/L=0.38;

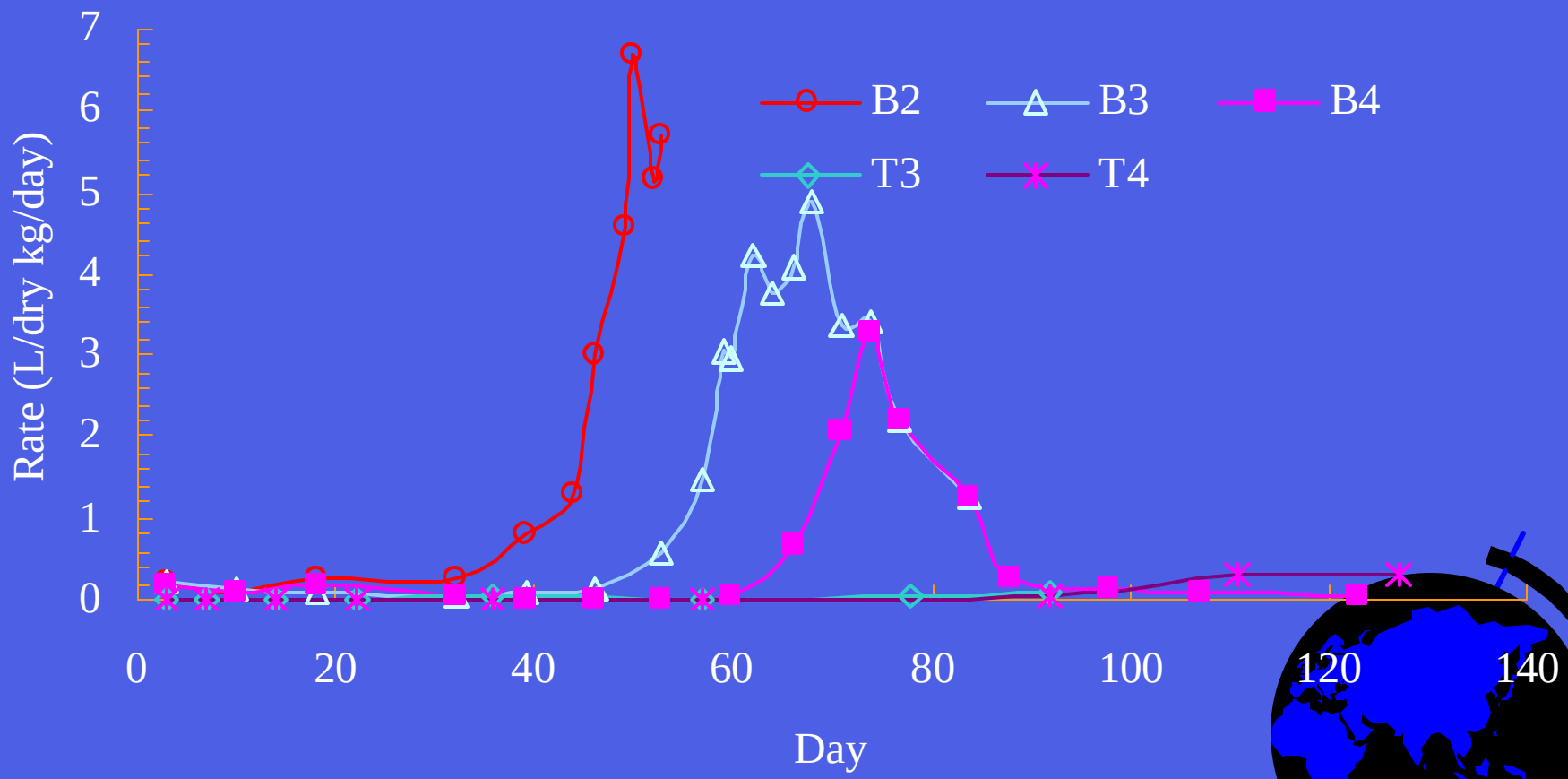
Direct Shear Equipment

- 100 mm Direct Shear Cell

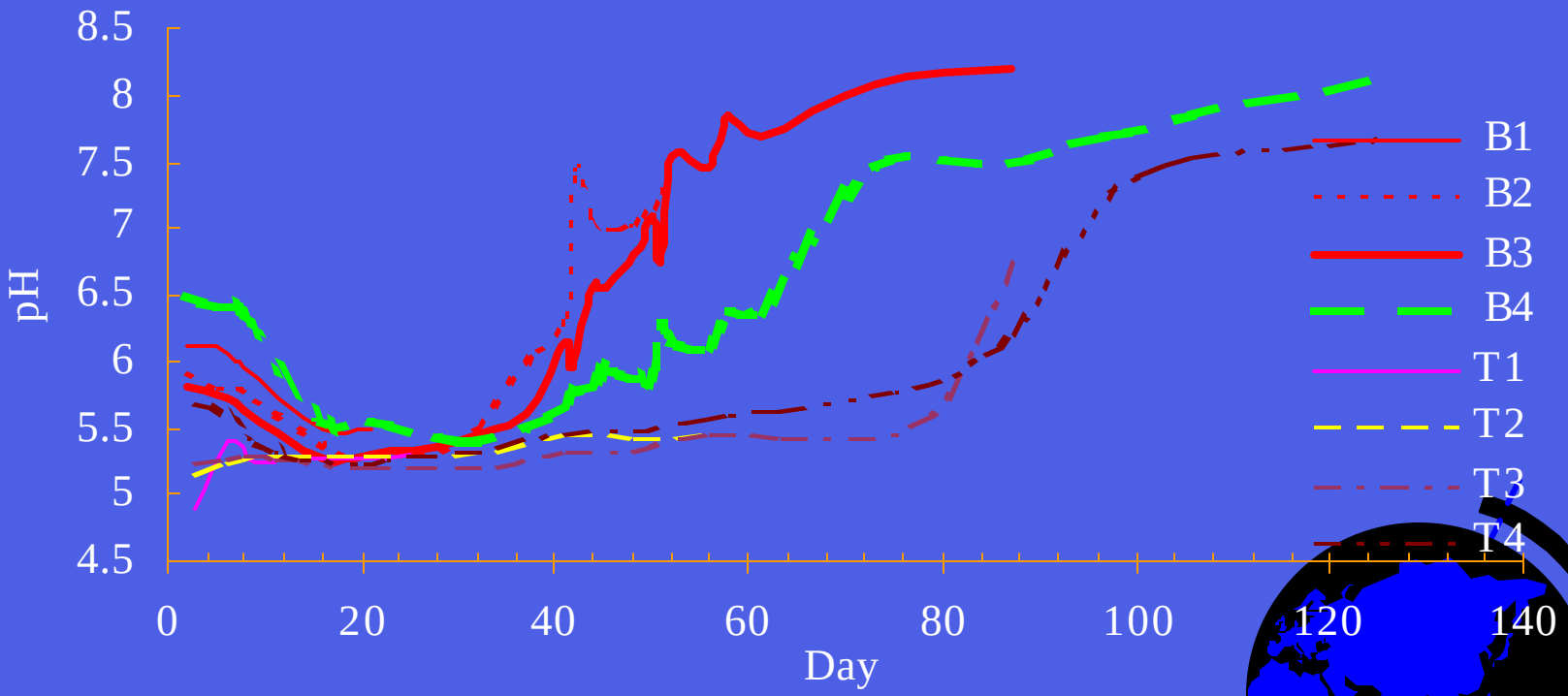
Result Discussions



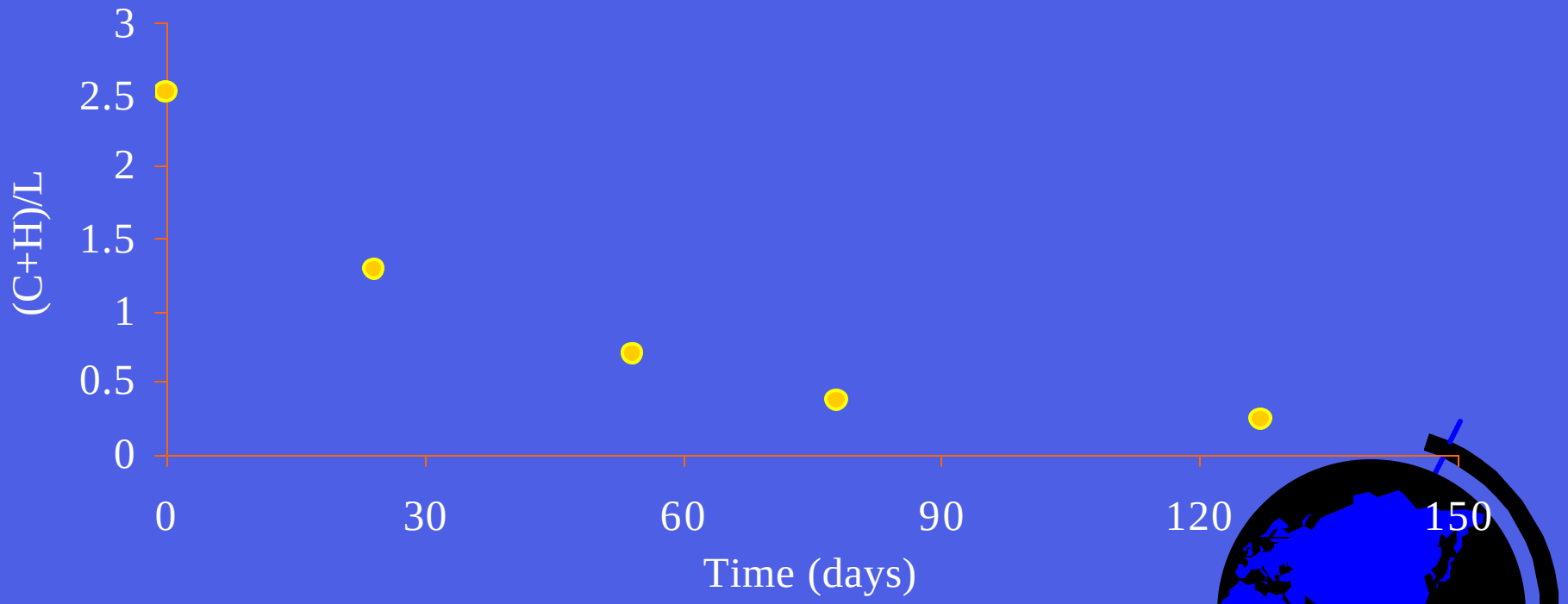
Methane Production Rate



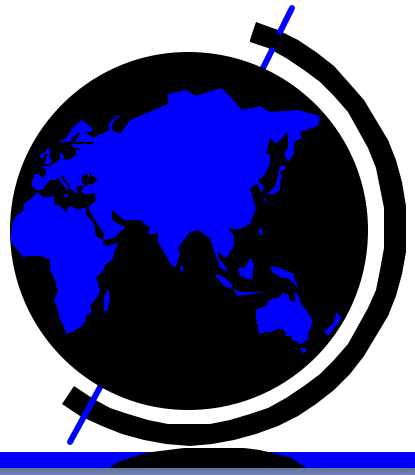
Monitored pH with Time



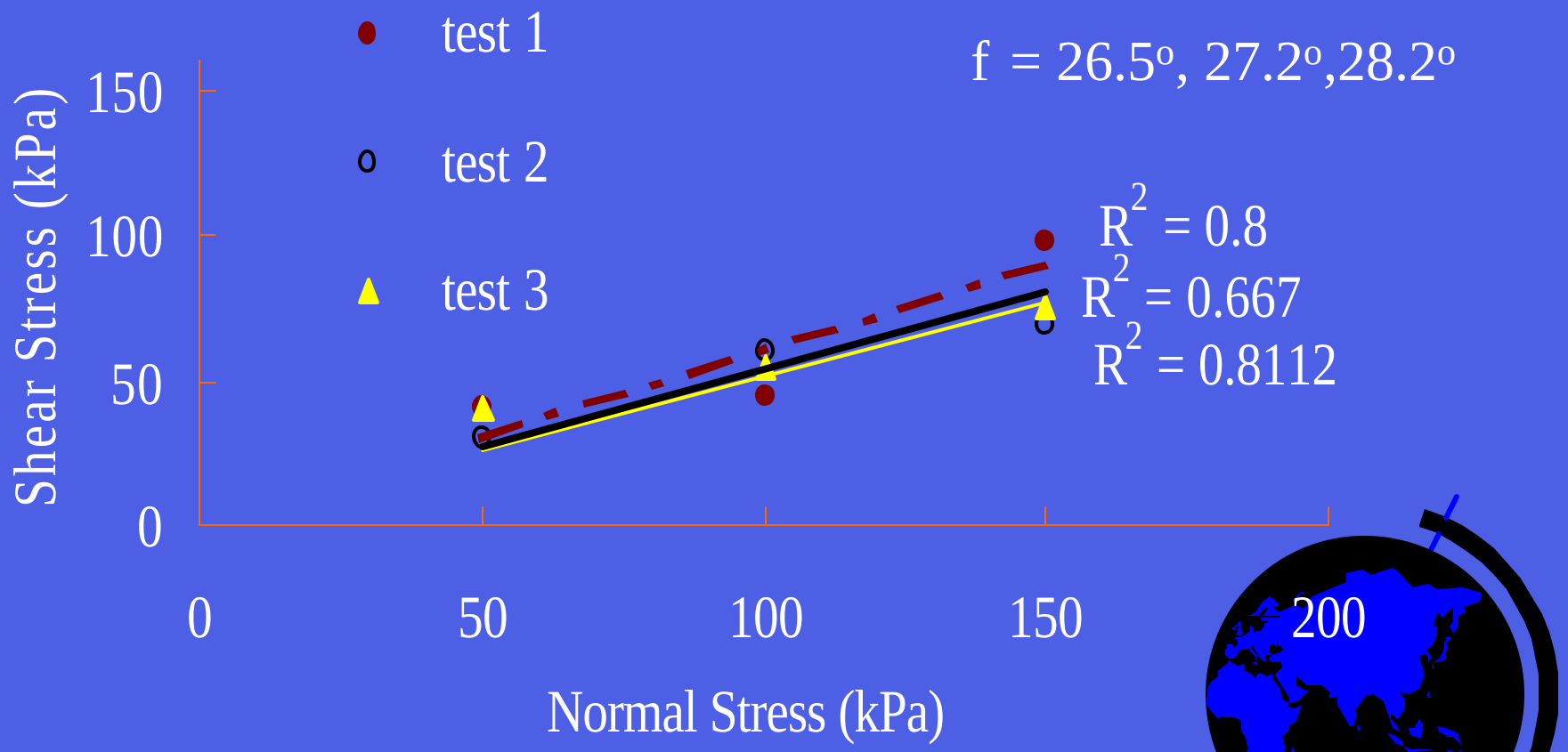
Monitored (C+H)/L ratio with Time



Shear Strength



Repeatability of Data – Shear Strength



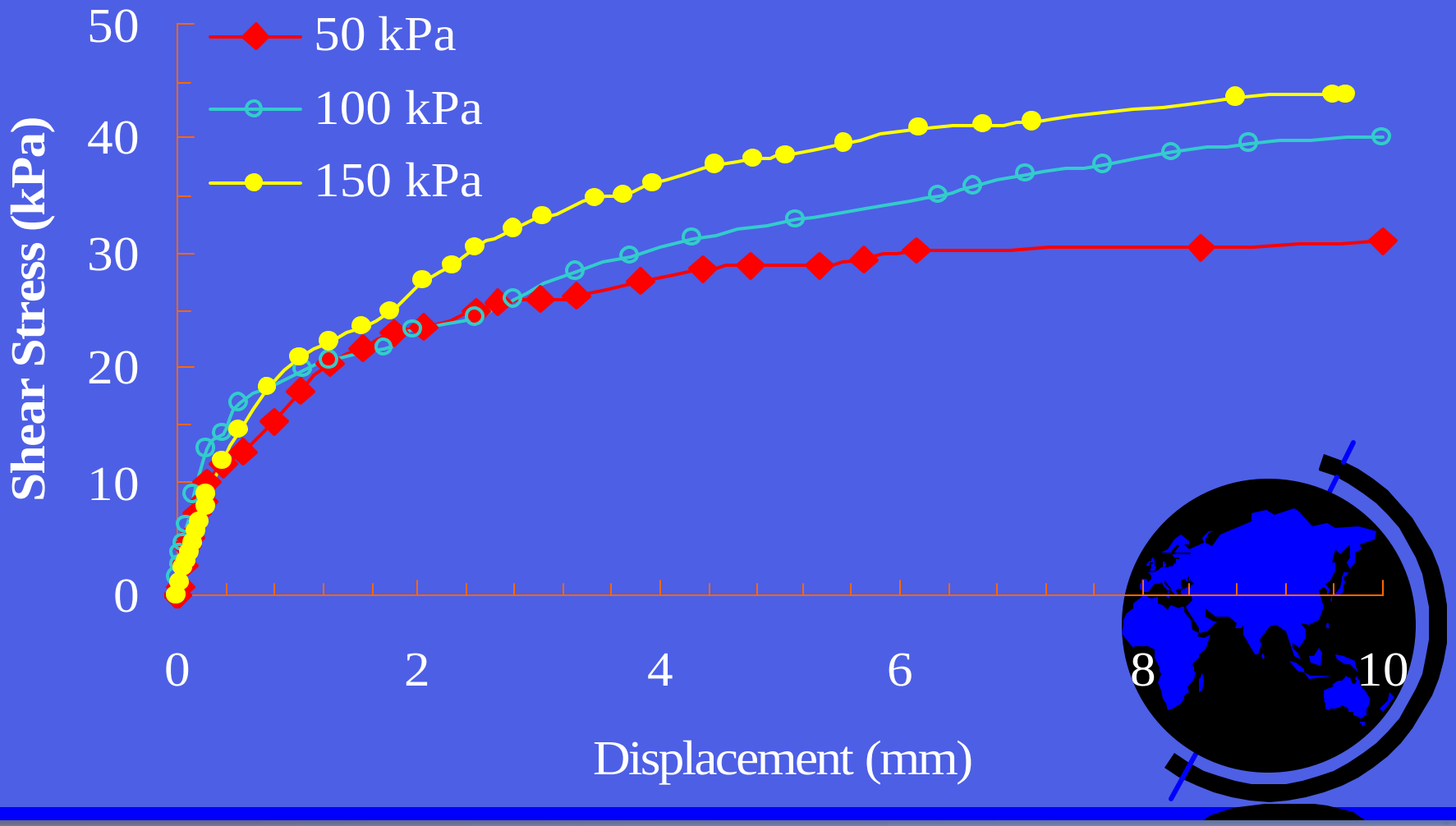
Shear Strength

- **Mobilized Strength Incompatibility**
- **Variation of Friction Angle with Degradation**

Major Components of MSW:

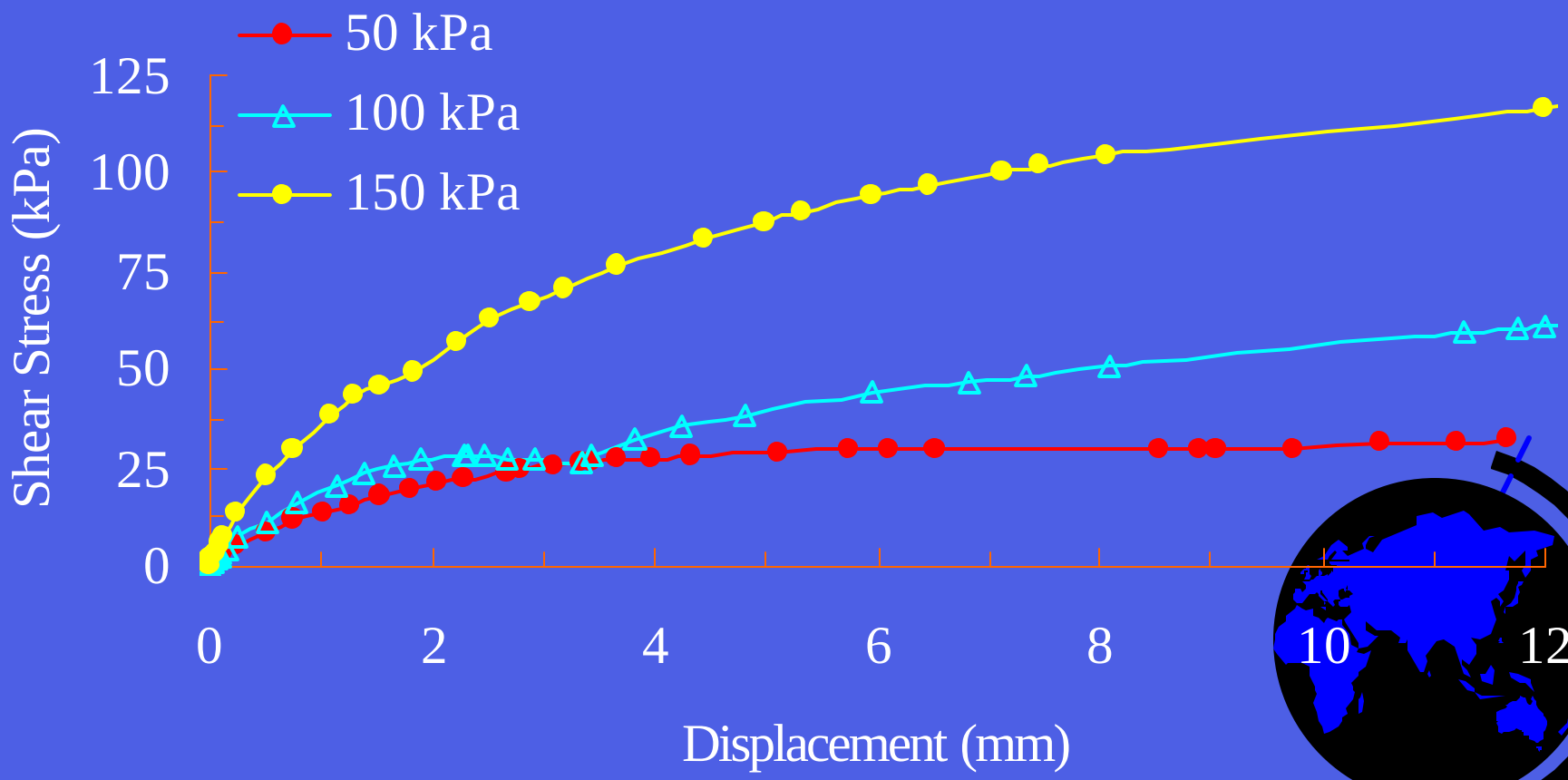
- Paper + Organics – 60-65%
- Plastics – 10-12 %

Shear Strength -Plastics



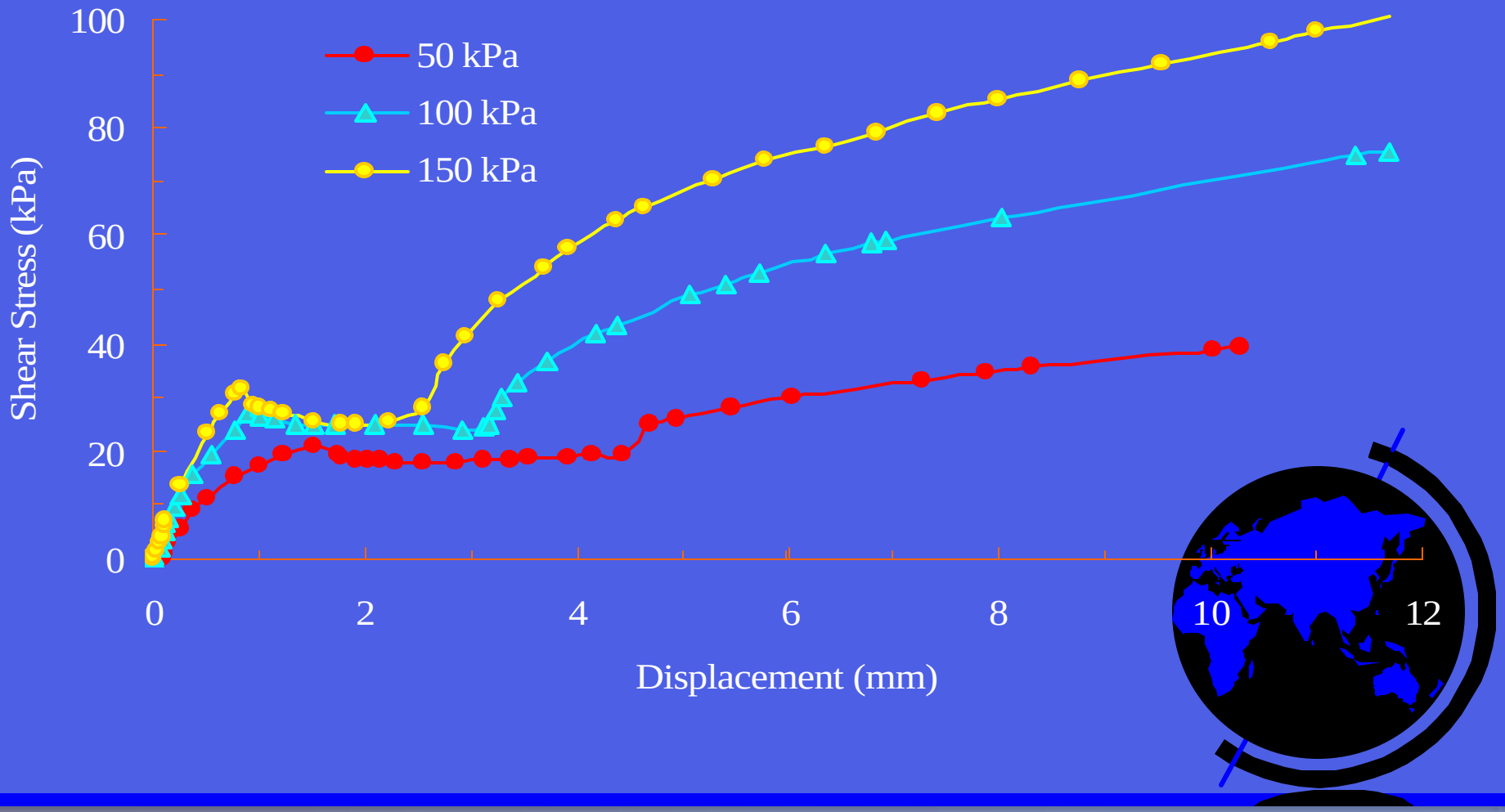
Shear Strength

Fresh Shredded Paper

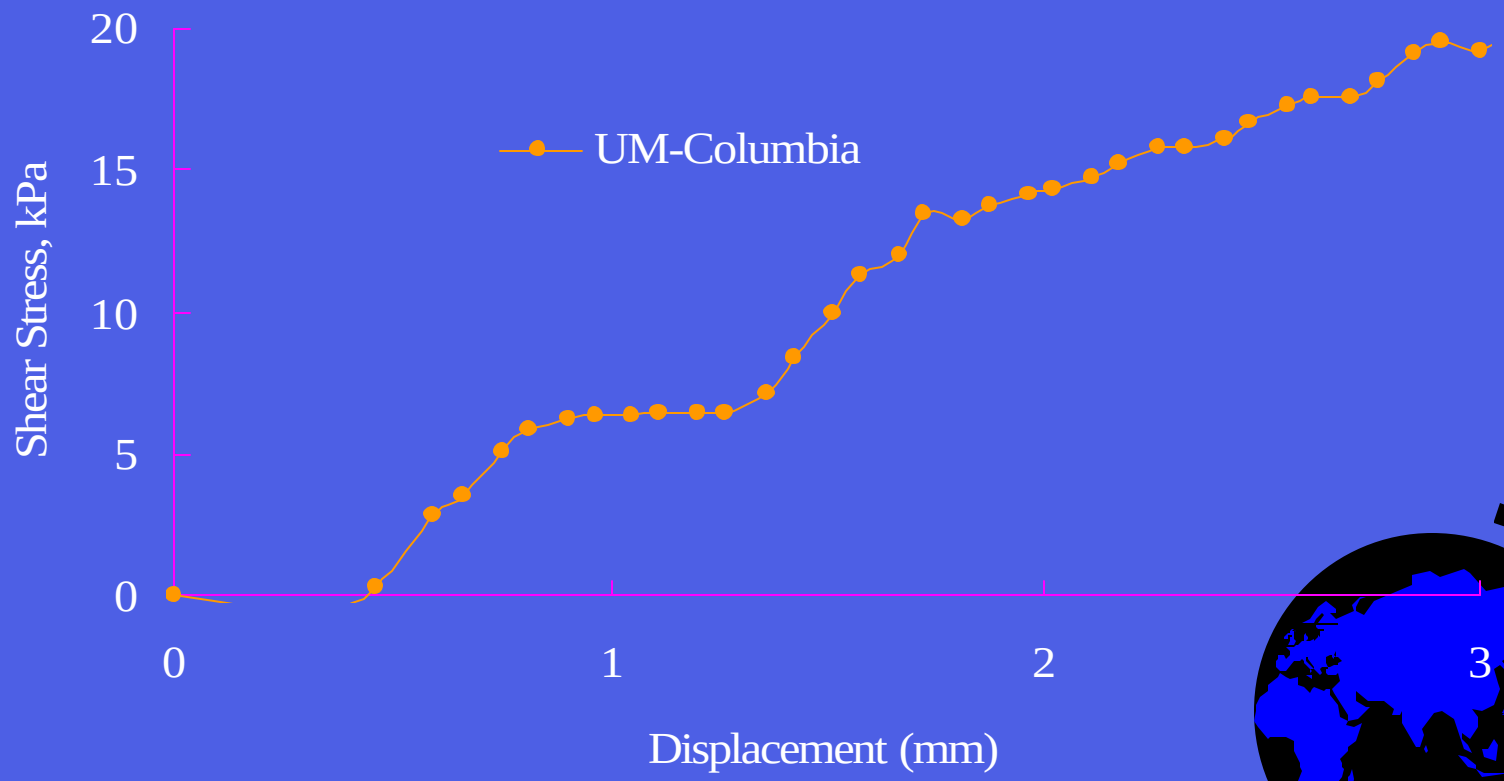


Shear Strength

Paper+textile+organics



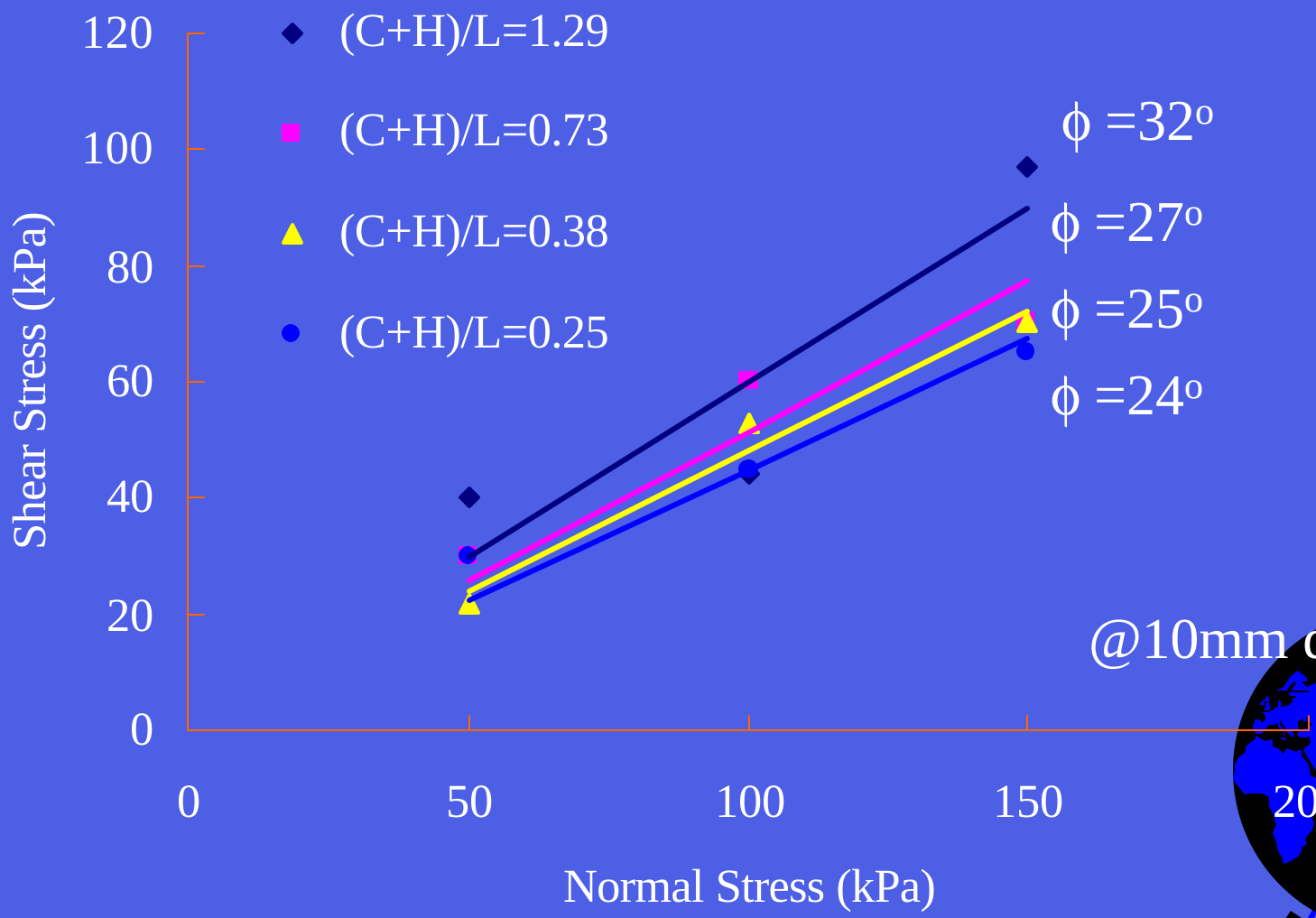
Shear Strength



Strength Incompatibility

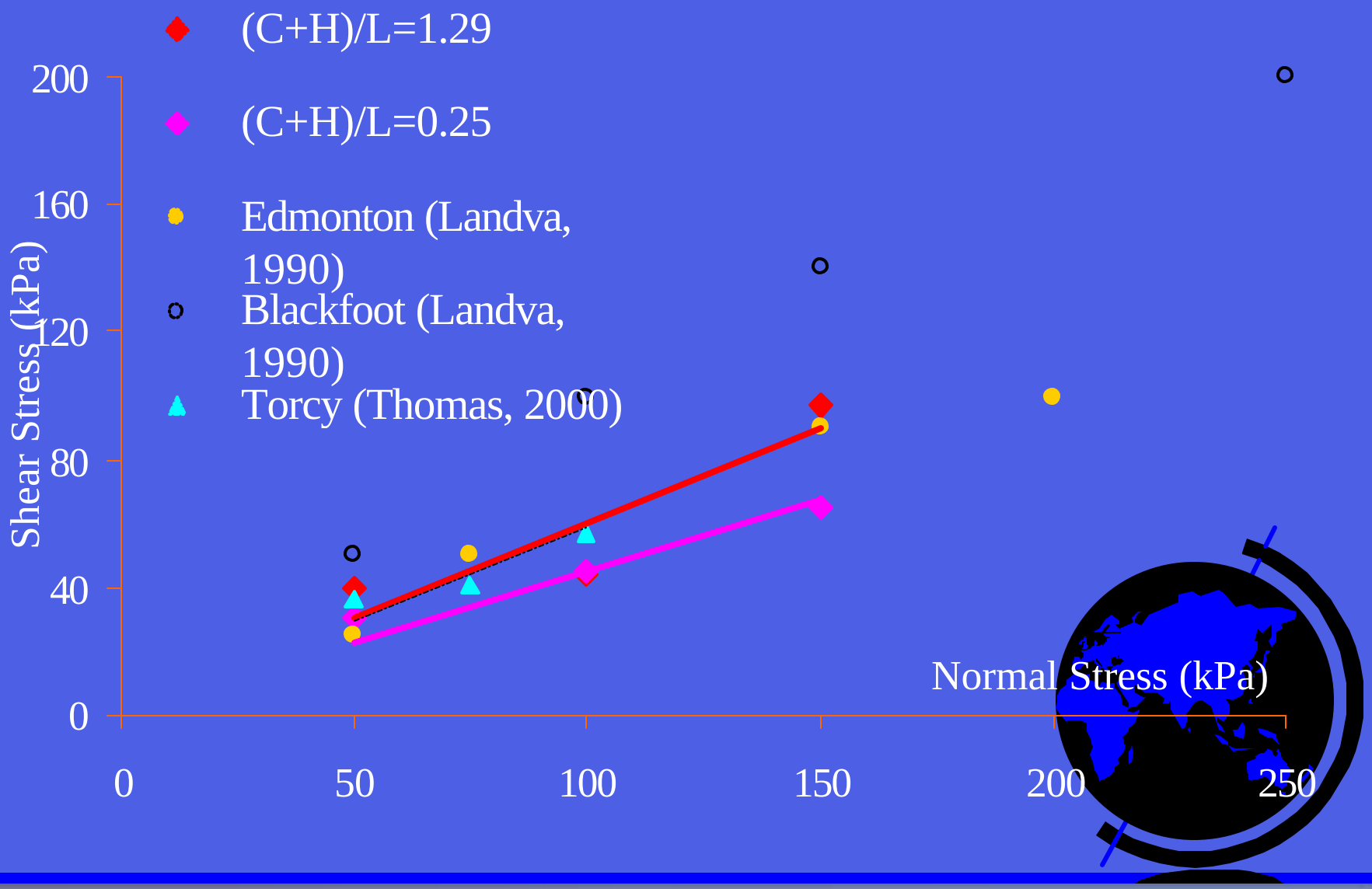
- MSW is made from materials having different stiffness characteristics
- Strength of different components mobilized at different deformation level
- Shape of shear stress-shear displacement curve depends on composition
- This means strength dependency on composition and deformation level
- This leads to the concept of Component Frequency and Sample Probability

Shear Strength with Degradation

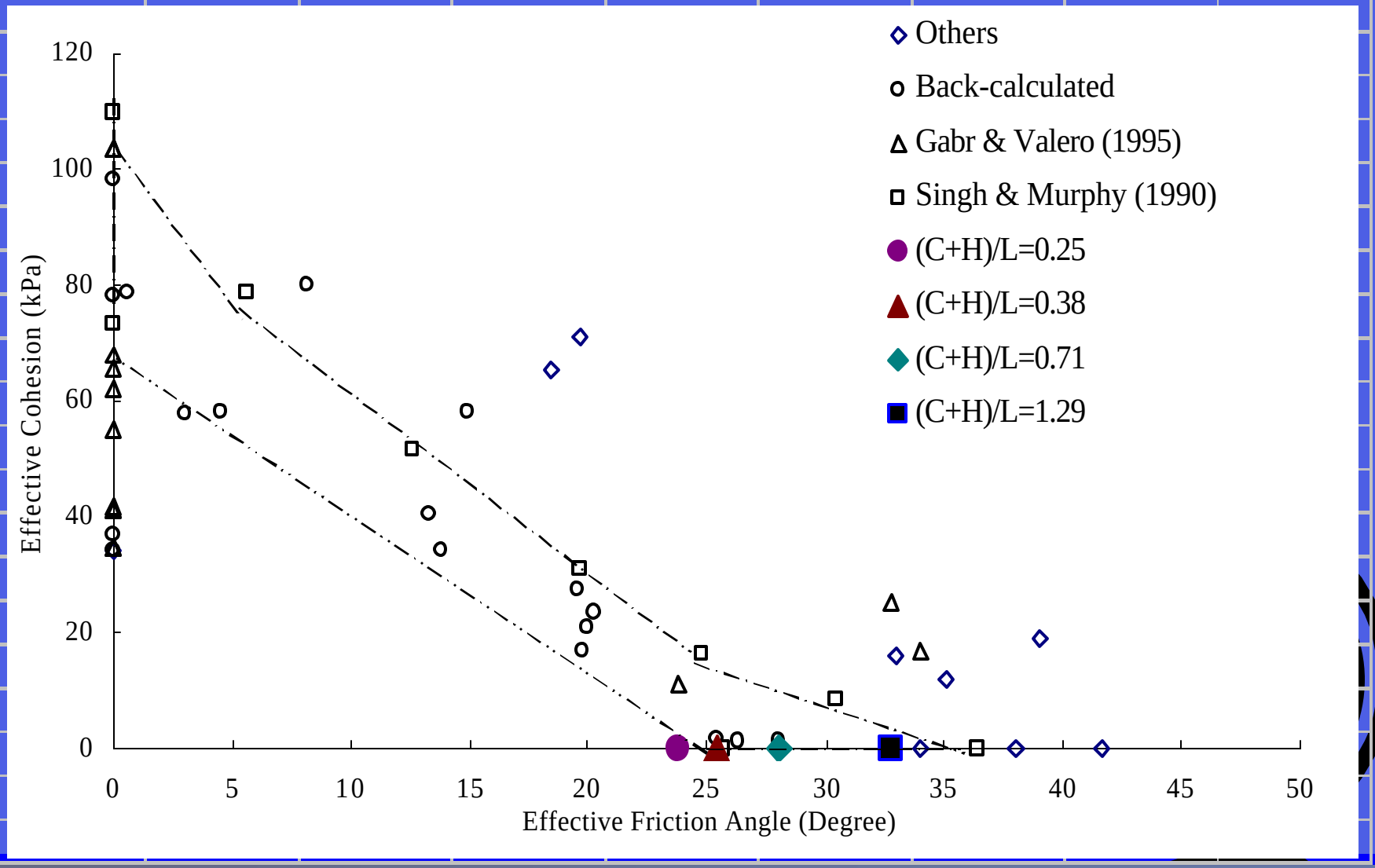


@10mm displacement

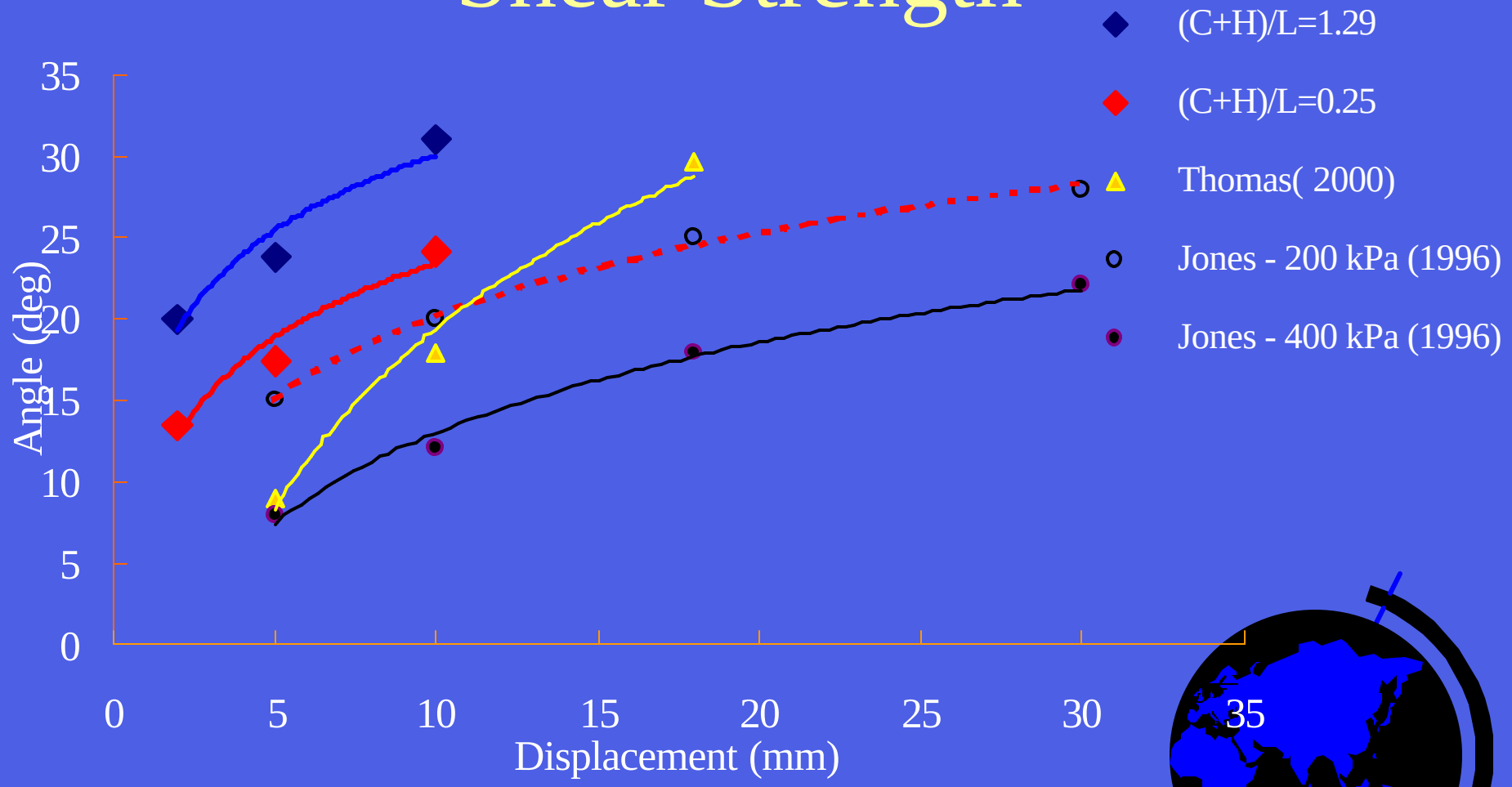
Shear Strength



Shear Strength



Shear Strength



Summary and Conclusions

- (C+H)/L, correlates with Strength parameters
- Mobilized strength incompatibility within the MSW components was observed due to presence of different type of materials
- Testing representative samples is essential
- What is a representative sample?
- Shear strength decreased with decomposition
- Strength increased with shearing displacement and failure envelope is non-linear