Lab Prep

Session 1: Fiber Reinforced Composites

CE 331

Spring 2014


Lab
Safety

Session 1 Objectives

- Measure E in flexure
- Measure variation in E with respect to reinforcement orientation

Materials

Session 1

Setup

Analysis

Report

Session 2

Background

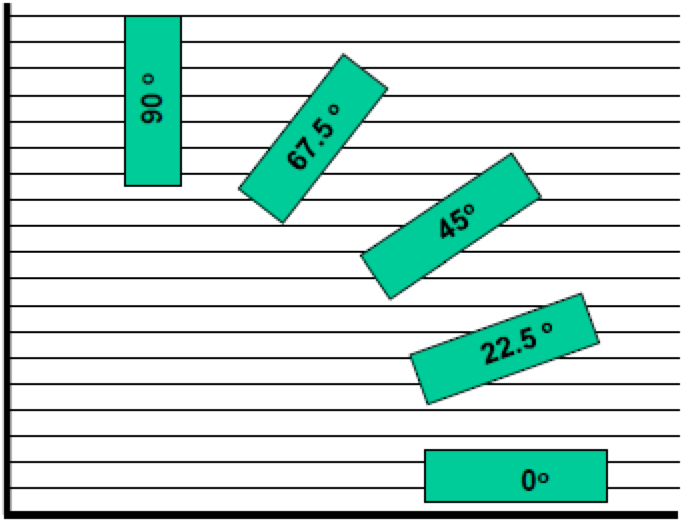
Setup

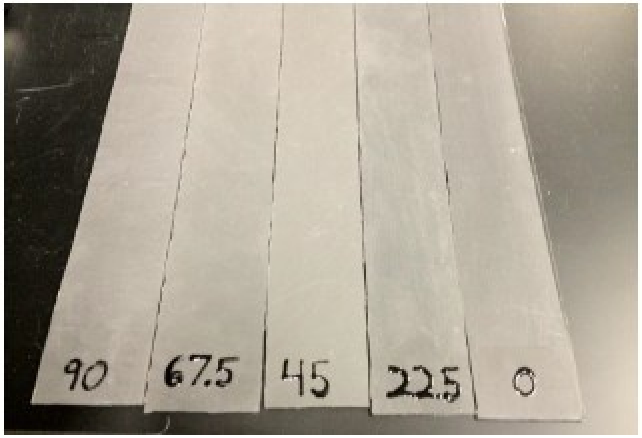
Task 1

Task 2

Task 3

- Continuous Fiber Reinforced Polymer (FRP)
- Cut from the same sheet at different angles
- These are brittle – be careful with them!

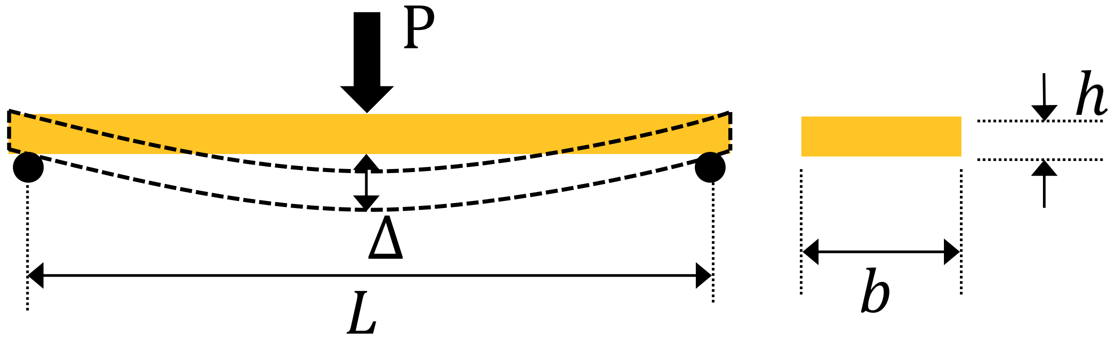




Edges can be sharp!

Midpoint Deflection

- E in flexure = beam deflection
- Similar to ASTM D143 for wood



- $$\Delta = \frac{PL^3}{48EI}$$

Δ: mid-span deflection (mm)
P: applied load (N)
L: length between supports (150mm)
E: Young's Modulus
I: moment of inertia ($bh^3/12$)

Experimental Setup

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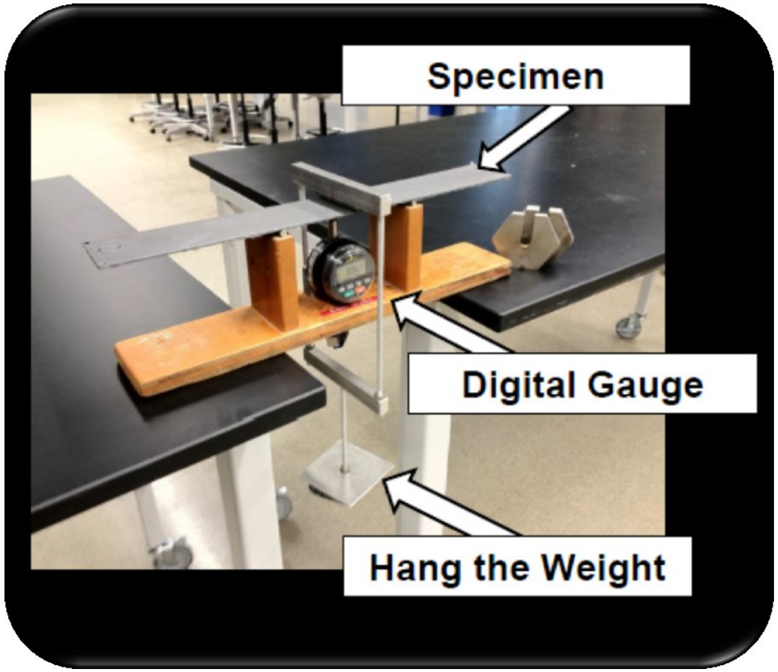
Setup

Task 1

Task 2

Task 3

- Width/thickness
- No weight – zero gauge
- Hang weight and read mdpt Δ
- Masses of: 500, 750, 1000, 1250 g

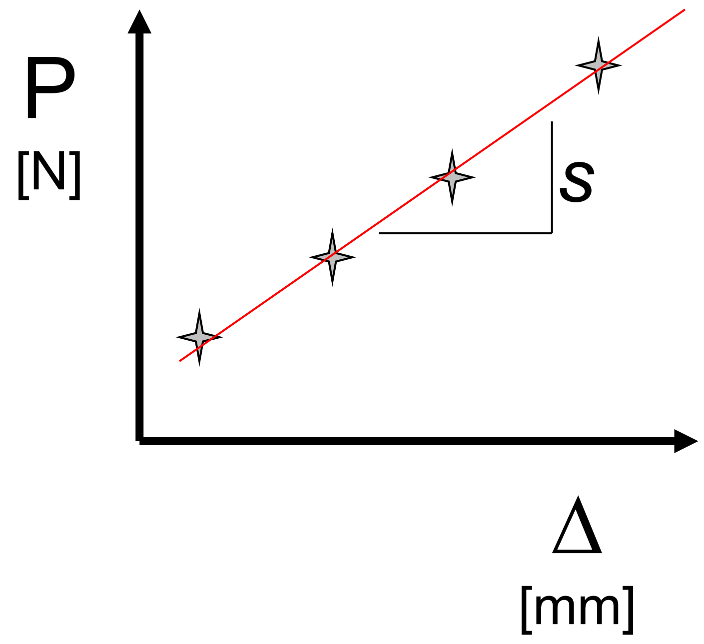


Weight [N] = mass [kg] * 9.81 [m/s²]

Calculations

For each specimen:

- Plot P vs Δ
- Linear Regression to find slope (s)
  - Non-zero intercept
- $\Delta = \dfrac{PL^3}{48EI}$
- $E = \dfrac{P}{\Delta}\dfrac{L^3}{48I} = s\,\dfrac{L^3}{48I}$
- All specimens on the same figure
- UNITS!



Reports

- Not meant to be a full lab report that you are probably familiar with
- There will not be a *minimum* length requirement
  - Grading will be based on content
  - A few reports during the semester will have a *maximum* limit
- Rubrics will be provided
- If you have questions, ASK US!

What to include in this Report

Session 1

Setup

Analysis

Report

Session 2

Background

Setup

Task 1

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Task 3

- This information is provided in the rubric
- Summary (<1 pg)
  - Goals/objectives
  - Method
  - Results/conclusions
- Results
  - Summary (slide 9)
  - Plot of P vs Δ
  - Plot of E vs θ
- Format/Organization
  - Structure
  - Spelling
  - Sig figs
- Appendix
  - Raw data table (slide 11)
  - Example hand calculation
  - Unit analysis

Example Summary Table

Cut Angle [deg]	Applied Load [N]	Mid-Pt Δ [mm]	Slope	E [GPa]
0				
22.5				
45				
67.5				
90				~ 6 GPa

Example E vs θ

Session 1

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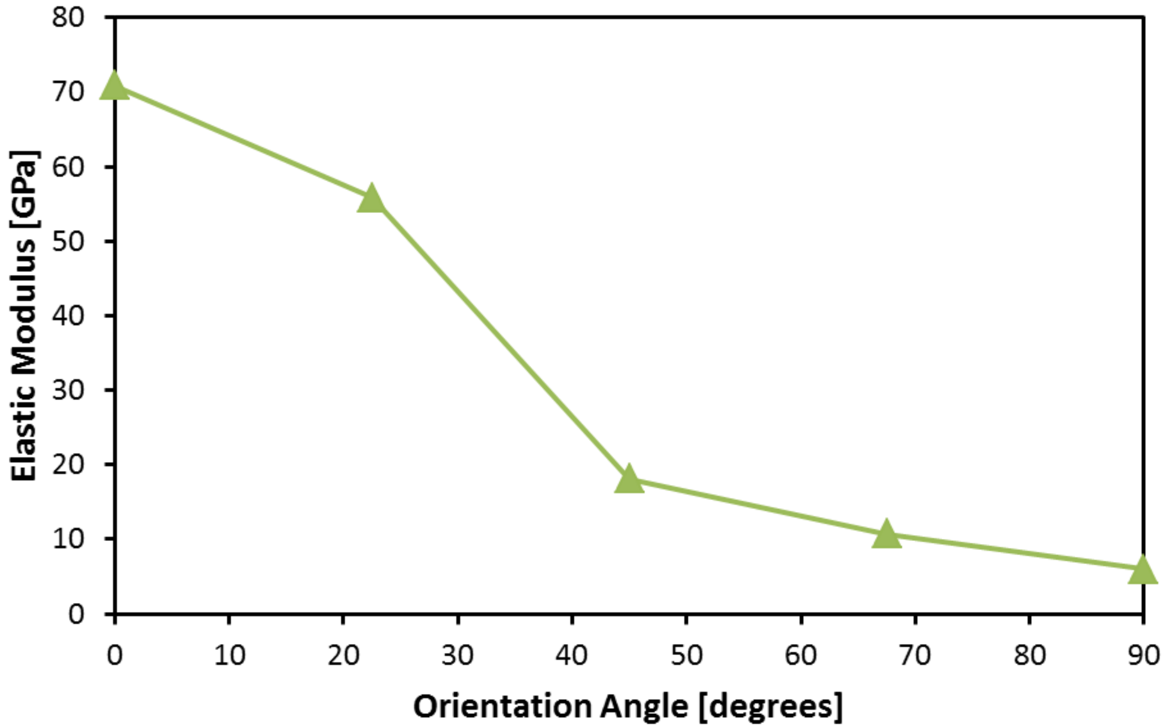


Figure 2: Elastic modulus as a function of reinforcement orientation

Data Table

Specimen #	Cut Angle [deg]	b [mm]	h [mm]	I [mm^4]	Measured Delection [mm]			
					500 g	750 g	1000 g	1250 g
1	0							
2	22.5							
3	45							
4	67.5							
5	90							

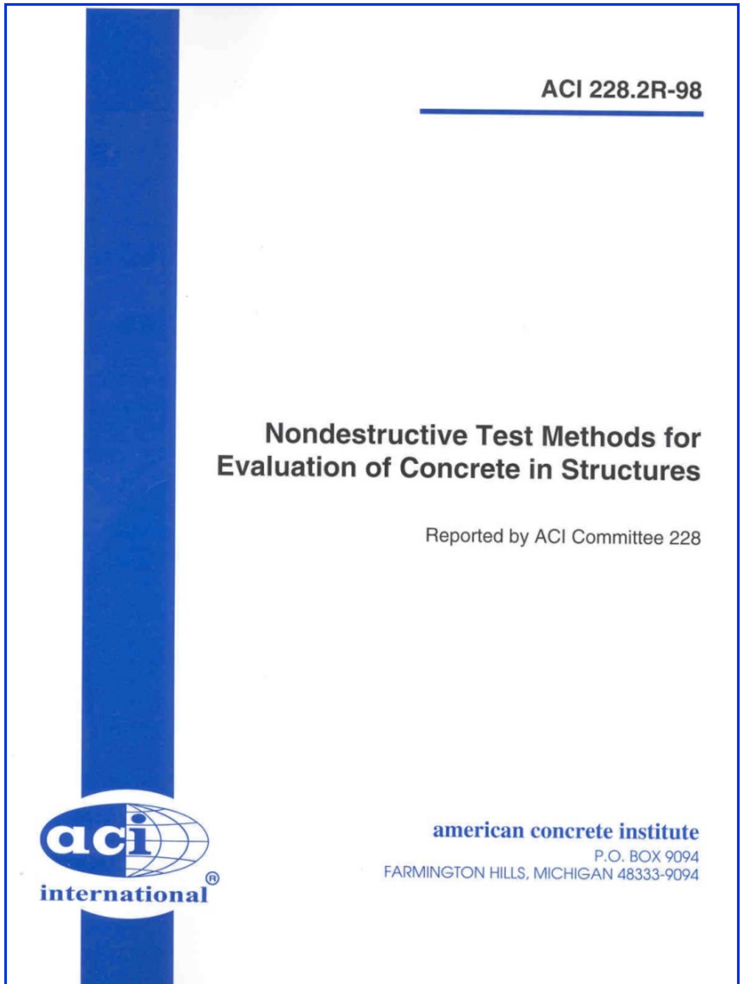
Lab Prep

Session 2: Particulate Composites and NDT

CE 331

Spring 2014

Non-Destructive Testing (NDT)



ACI 228.2R-98

Nondestructive Test Methods for
Evaluation of Concrete in Structures

Reported by ACI Committee 228

aci international

american concrete institute
P.O. BOX 9094
FARMINGTON HILLS, MICHIGAN 48333-9094

- In situ properties
- Typically strength / stiffness
- Member thickness
- Defects
- Reinforcement
- More recent: durability

Rebound Hammer

- 50,000+ Sold World Wide
- Can Be Conducted in Any Direction
- Correlate with Cylinders with Indents at 120 Degrees
- ASTM C805
- +/- 15-20%

Push Hammer (Store Energy)

Pin Released

Rebound Measured

Rebound Hammer

Session 1

Setu

Analy

Repo

Sessio

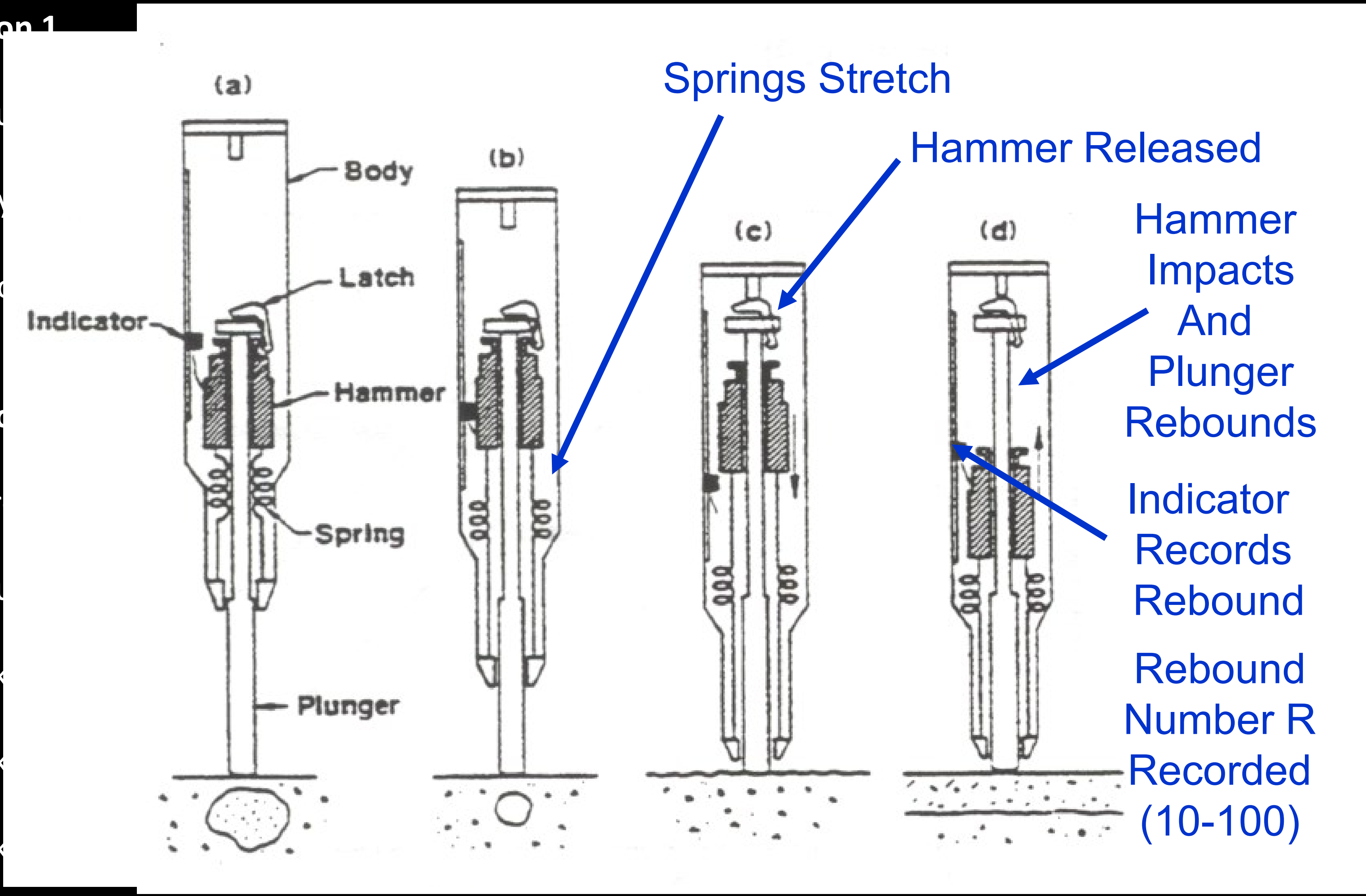
Backgr

Setu

Task

Task

Task



Data Analysis

Session 1

Setup

Analysis

Report

Session 2

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Setup

Task 1

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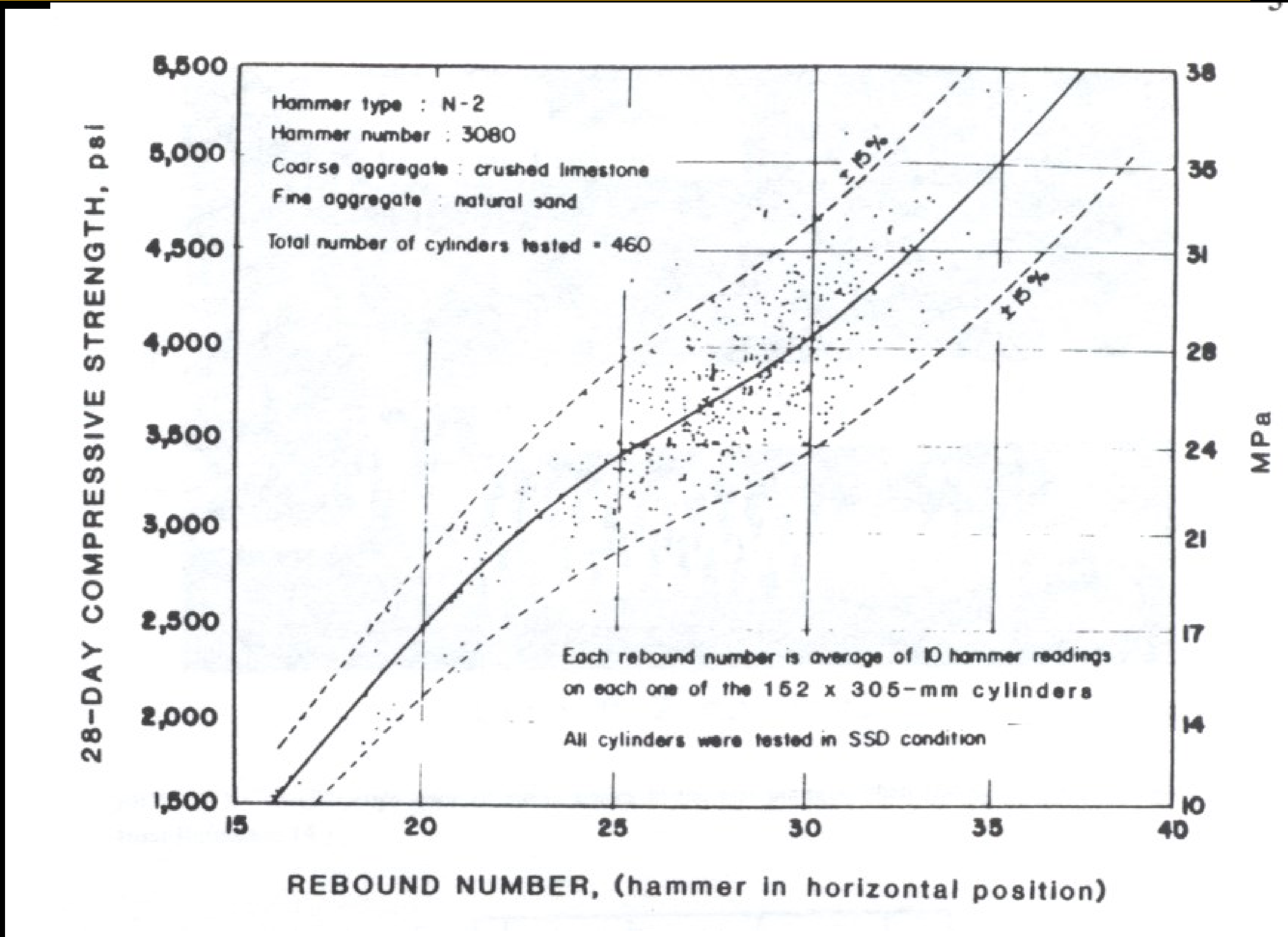
Task 3



Drawbacks

Session 1

Setup

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Setup

Task 1

Task 2

Task 3

- Measure of How Much Energy is Absorbed
- Related to Stiffness (Strength of Concrete)
- Aggregate Dependence
- Sensitive to Local Conditions (Average of 10 Values Reported)
- Near Surface Layer Measurement – Not Core Concrete
- Sensitive To Moisture Conditions at Surface
- Surface (Trowel or Plywood Forms Higher)
- Calibrate with Local Materials
- Rigidity of Test Samples

Ultrasonics

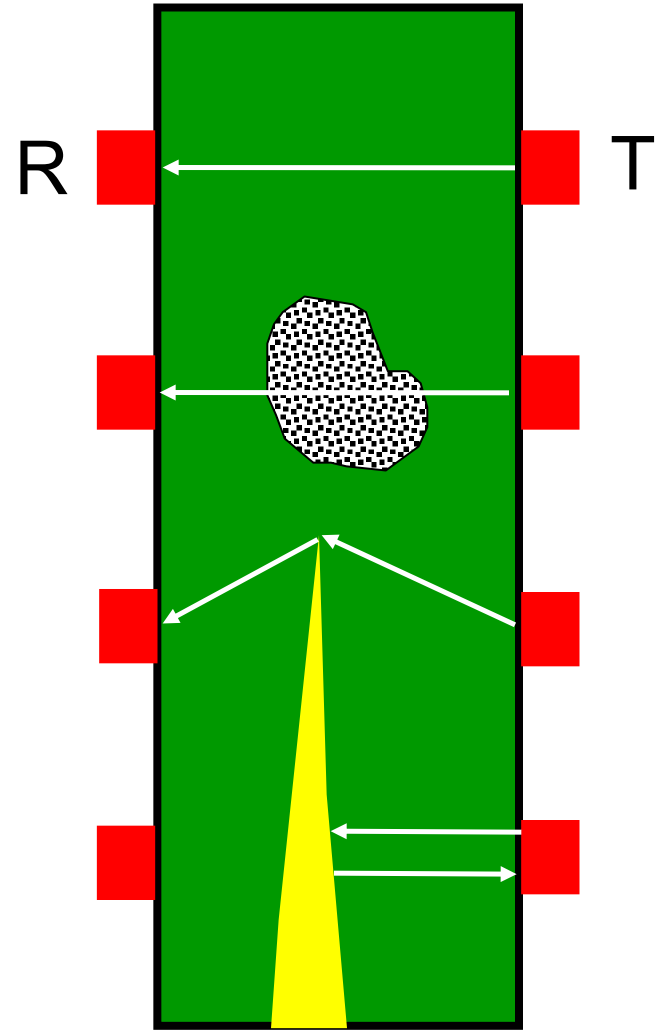
- Similar to radar, medical ultrasound
- Above audible sound freq
- Sound/Stress waves
- Piezoelectric material converts electricity into stress waves

Benefits

- May Be Required to Assess To Find Out What Quality of Concrete Was Placed (QC/QA new construction, troubleshooting problems)
- Condition Evaluation of Older Concrete (rehab), Increasingly Common to Find Structures “Deteriorating” From Materials Related Problems
- Quality Assurance of Concrete Repairs
- Able to Assess Large Volumes of Concrete Rapidly

Principle

- Sound waves travel through materials
- Defects influence travel time
- Voids can reflect or alter wave direction



Speed of Sound

Session 1

Setup

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Session 2

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Task 1

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Task 3

- Sound travels through materials
- $f\left(\frac{E}{\rho}\right)^{1/2}$

E:elastic modulus
ρ:density

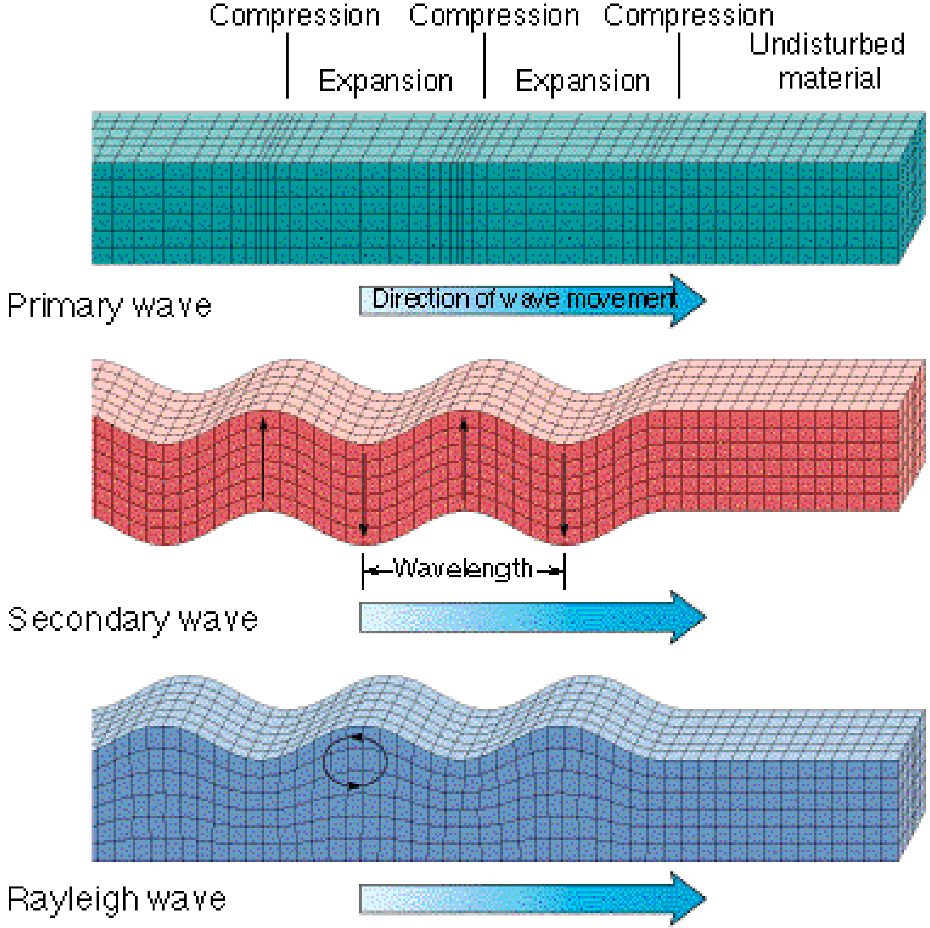
Air　　Water　　Solid

$C_{Air} < C_{Water} < C_{Solid}$

Types of Waves

- Session 1
- Setup
- Analysis
- Report
- Session 2
- Background
- Setup
- Task 1
- Task 2
- Task 3

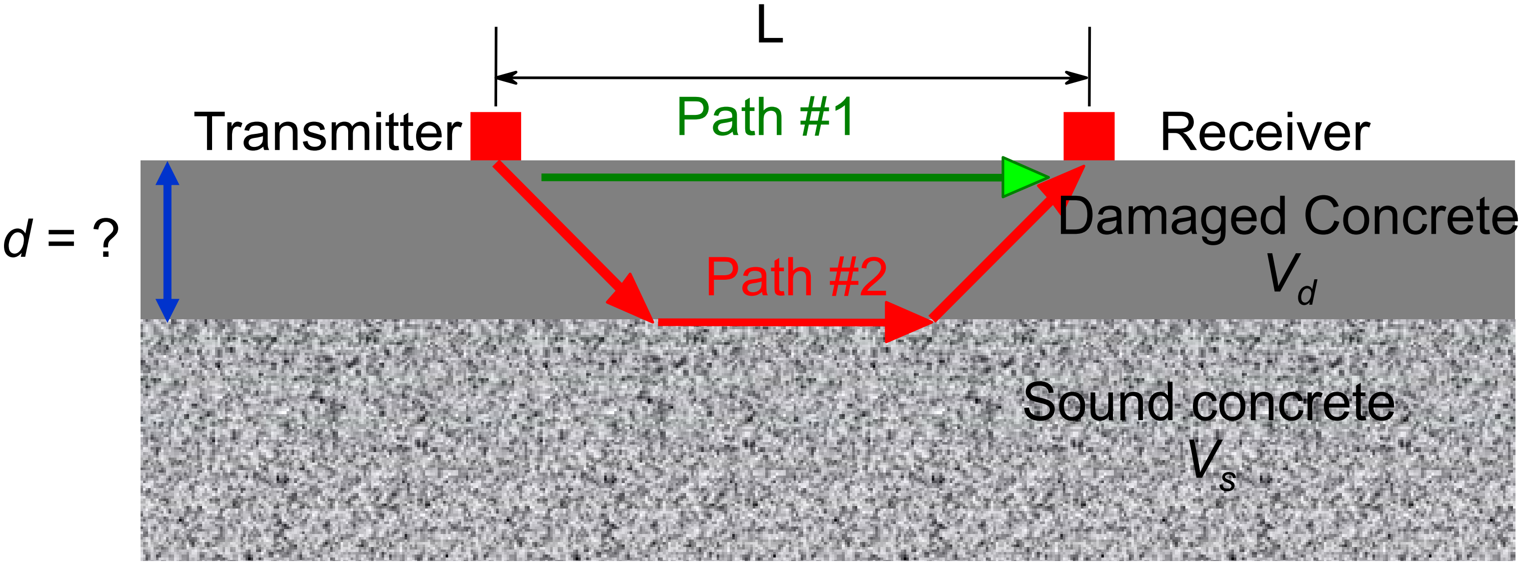
- Primary**
  - P-wave
  - compression
- Secondary
  - S-wave
  - shear
  - transverse
- Rayleigh
  - surface



http://www.darylscience.com/Demos/PSWaves.html

Indirect Transmission (Ultrasonic Pulse Velocity) ASTM C 597

Measure travel time as a function of distance, *L*, between transducers; determine depth of interface, *d*



Determine "d"

Session 1

Setup

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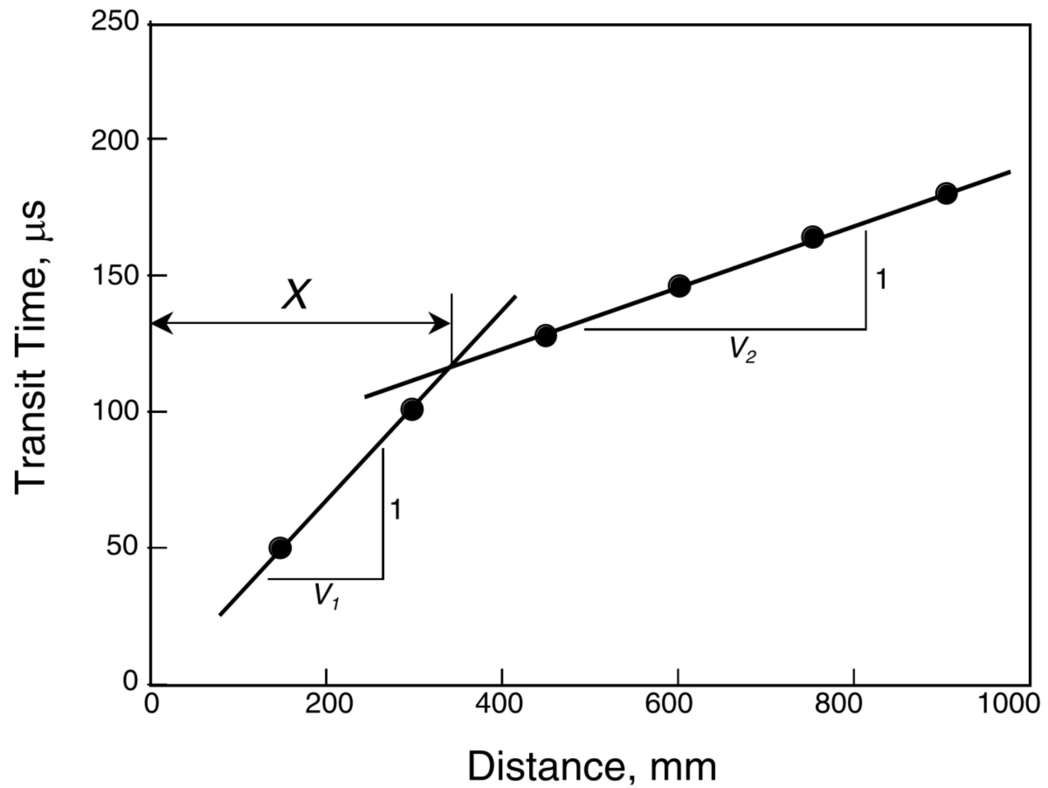
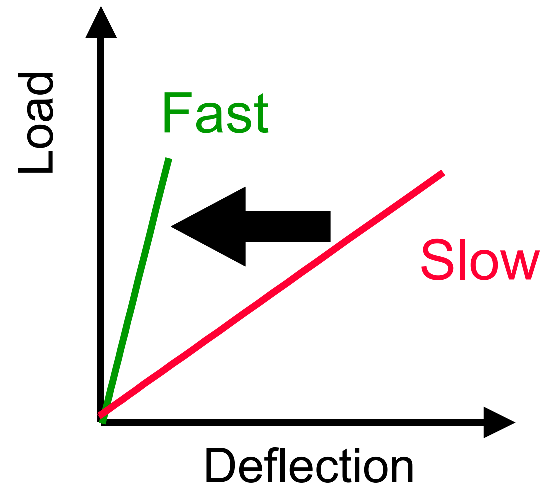


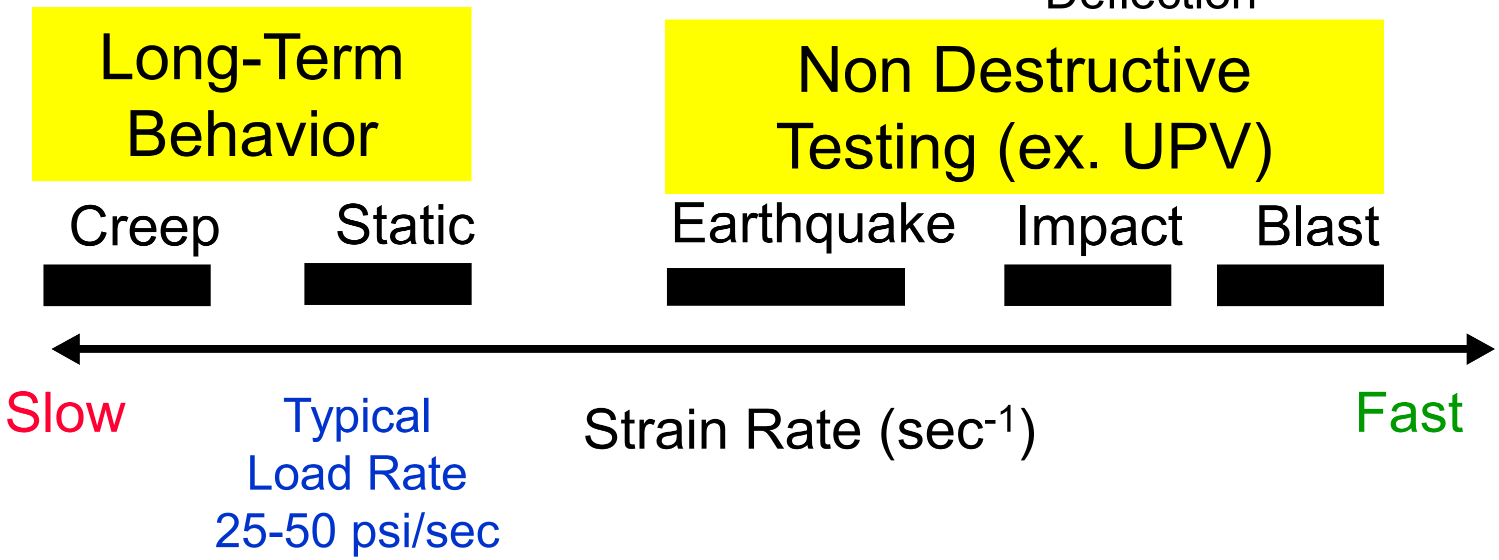
$$d = \frac{X}{2}\sqrt{\frac{V_2 - V_1}{V_2 + V_1}}$$

Naik, Malhotra, Popovics

Rate Effects

- Viscoelastic response
  - Later in semester
- Faster = Stiffer





UPV Machine (1970s)

Session 1

Setup

Analysis

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Background

Setup

Task 1

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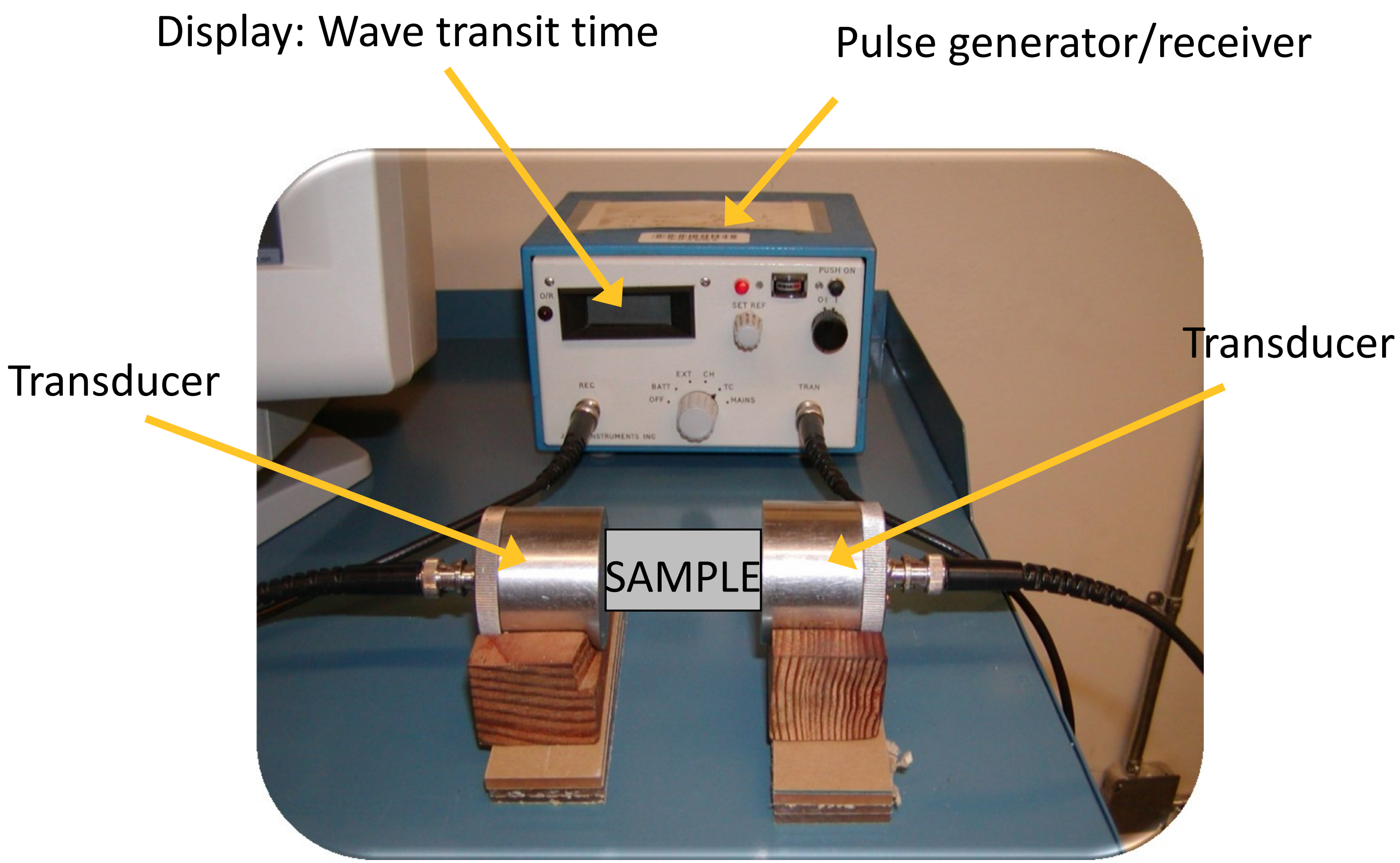
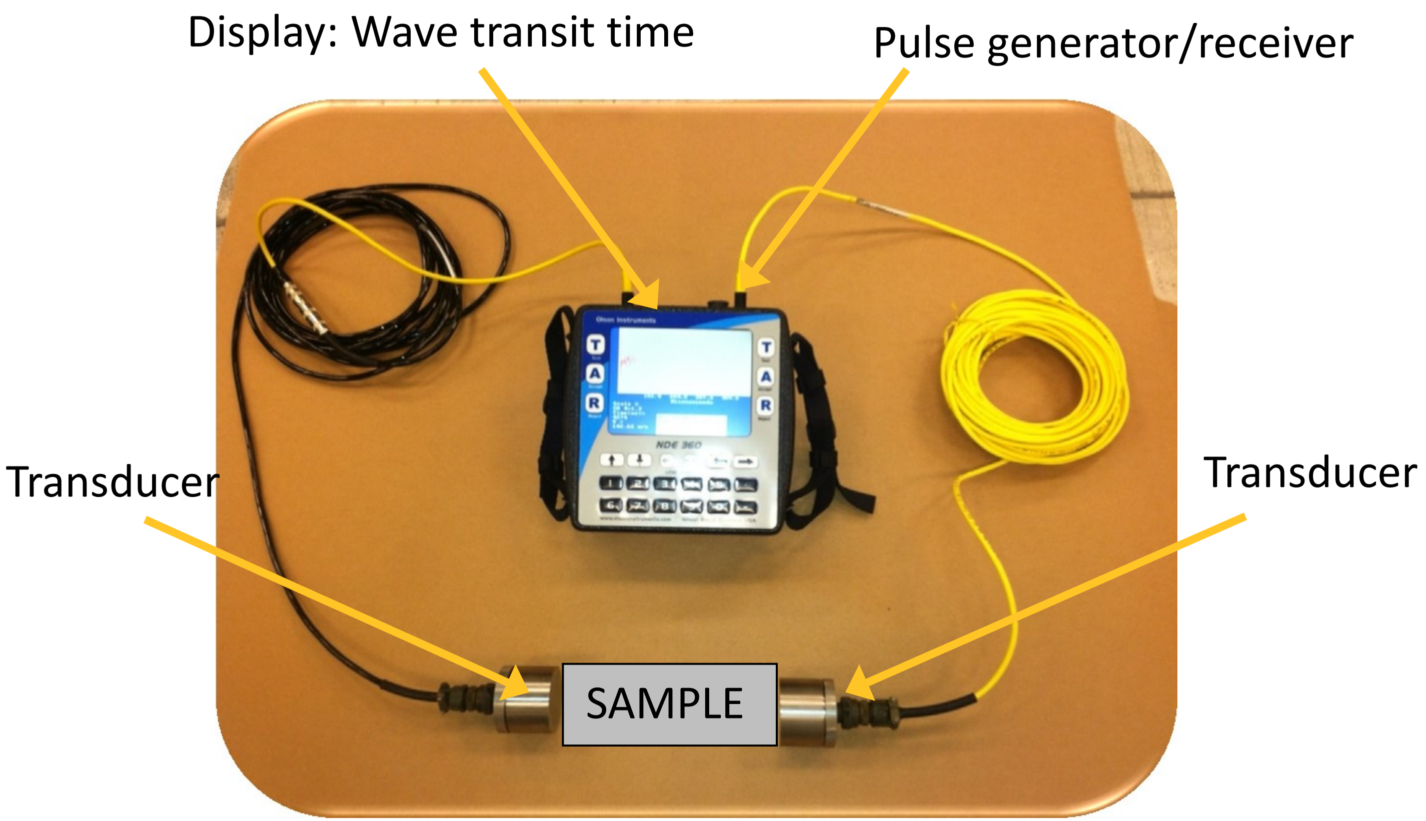
Task 3

Pulse generator/receiver has a timer which measures the transit time (μs)



UPV Machine (2011)

Pulse generator/receiver has a timer which measures the transit time (μs)



Wave Speed

Session 1

Setup

Analysis

Report

Session 2

Background

Setup

Task 1

Task 2

Task 3

- Machines give transit time (t)
  - $C = \frac{L}{t}$

C: wave speed [m/s]

L: dist. between electrodes or length of sample [m]

t: transit time [s] (convert from what's given on machine in μs)

For some reason, convention in this field uses "C" for wave speed

  - $C = \sqrt{\frac{E(1-\mu)}{\rho(1+\mu)(1-2\mu)}}$

*this is good only for p-waves

C: wave speed [m/s]

μ: Poisson's ratio

ρ: density [kg/m^3]

Session 2 Objectives

Session 1

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Analysis

Report

Session 2

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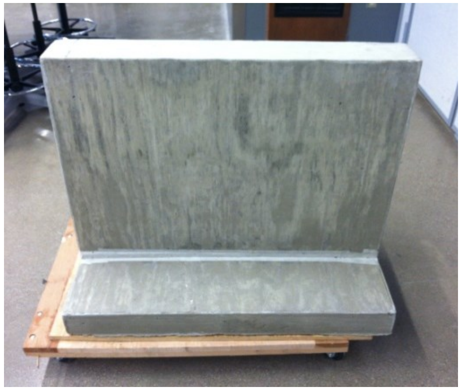
Setup

Task 1

Task 2

Task 3

- Learn the principles of dynamic non-destructive testing (NDT), technology known as ultrasonic pulse velocity (UPV)
- Determine E of common homogeneous materials
- Determine E of plaster/alum composites
  - Volume fraction effects
- Evaluate structural integrity in the field



Task 1: Homogeneous Materials

- Measure mass and dimensions (ρ)
- Measure transit time
- Compute velocity

SAMPLE	Mass (g)	Length (mm)	Diameter (mm)	Time (μs)	Speed (m/s)
Steel					
Copper					
Aluminu m					
HDPE					
Glass					

Task 1: Homogeneous Materials

- Compute E
- Compare to literature values
  - Credible sources
  - http://www.engineeringtoolbox.com/young-modulus-d_417.html
  - Why might there be differences?
- Summary Table

SAMPLE	Density (g/cm^3)	Pulse Velocity (m/s)	Elastic Modulus (Gpa)
Steel			
Copper			
Aluminum			
HDPE			
Glass			

Task 2: Particulate Composites

- Plaster Matrix / Aluminum dispersion

- 5 specimens
  - 100 % plaster
  - 100 % Al
  - 3 composites

E v V_{al} (Fig. 3)

Session 1

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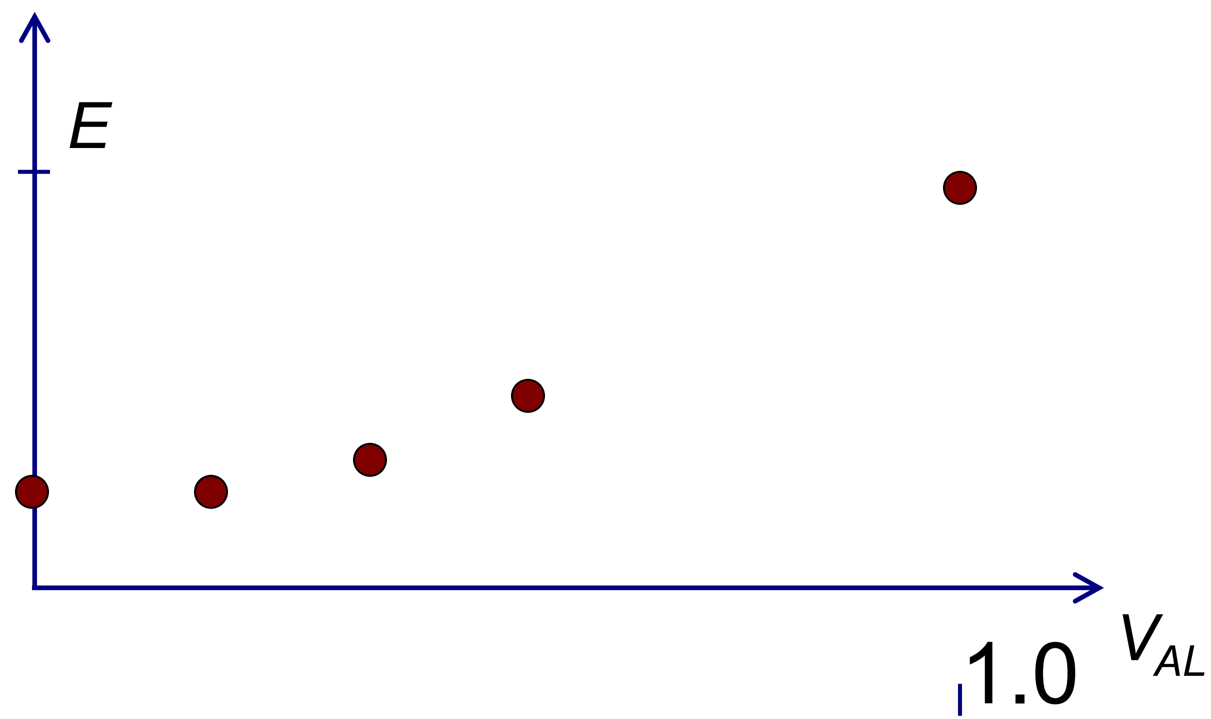
Task 3

- Experimental Data Points of E v V_{al}



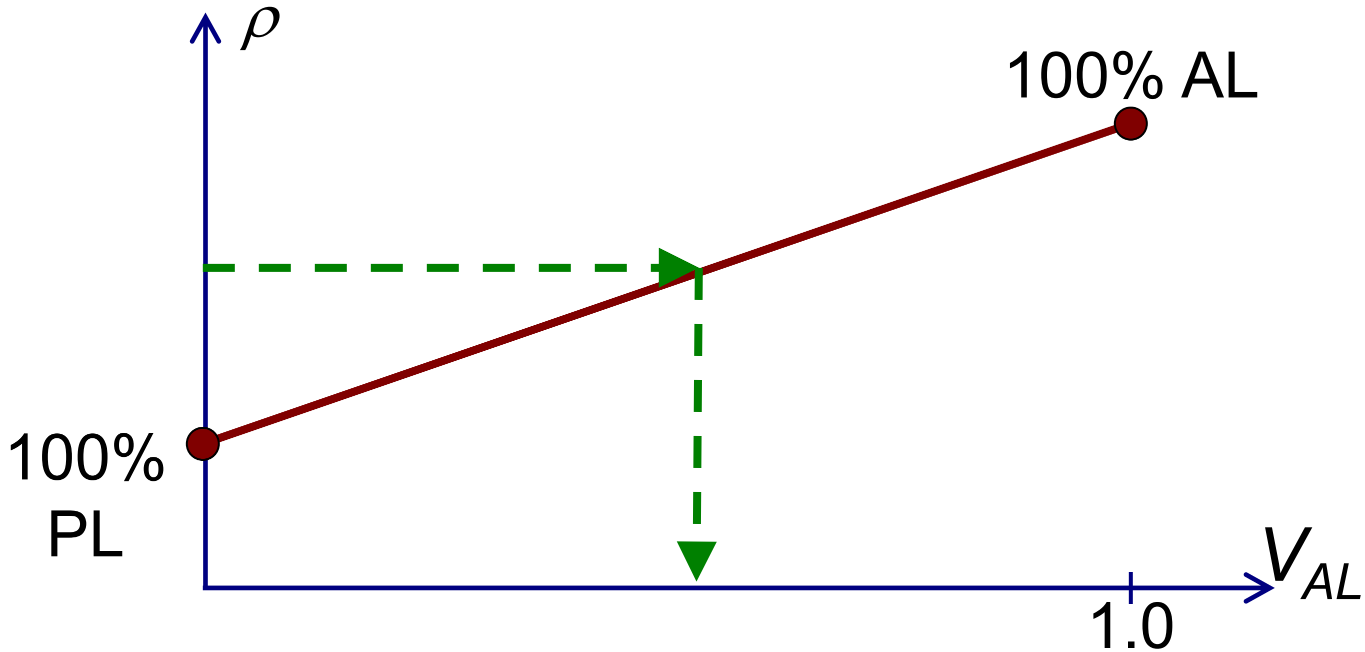
Calculations

- Measure transit time
- Compute velocity
- Elastic Modulus
  - $C = \sqrt{\frac{E(1-\mu)}{\rho(1+\mu)(1-2\mu)}}$

    For some reason, convention in this field uses "C" for wave speed
  - μ and ρ are different for each sample (see previous slides)

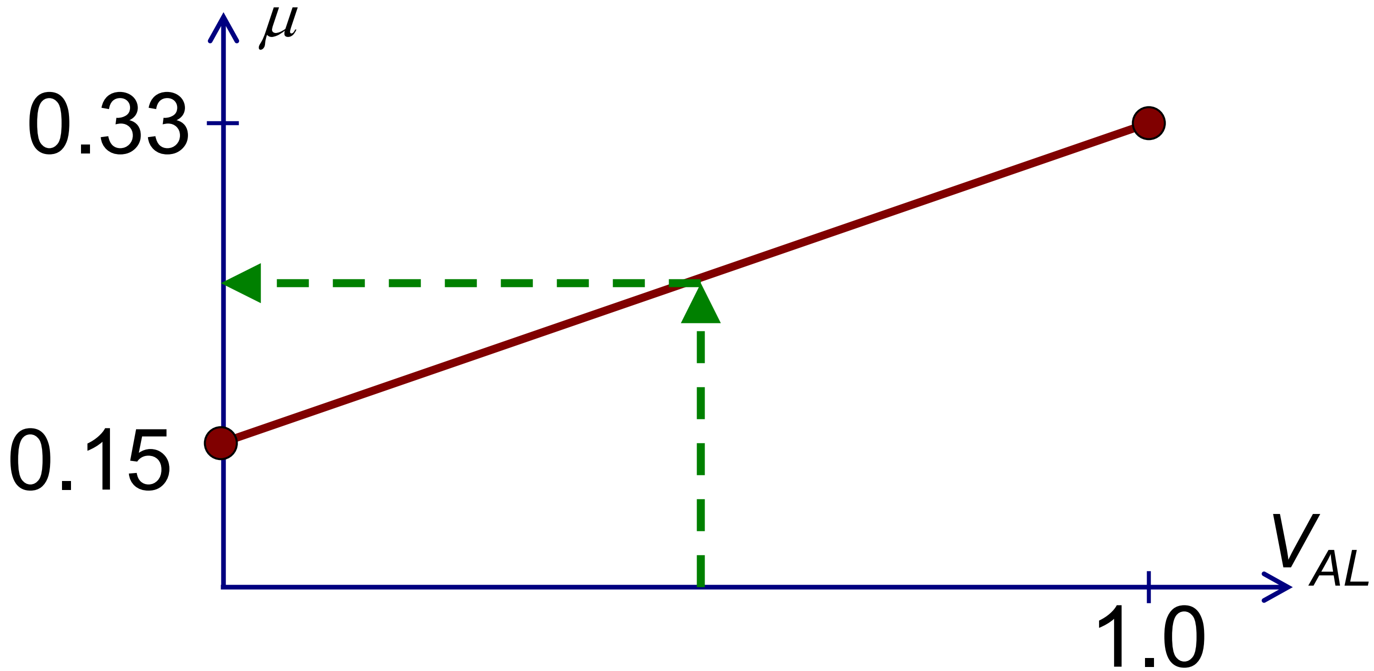
Determine ρ and V_{al} (Fig. 1)

- Mass / dimensions$\rightarrow$ ρ
- Determine V_{al} for each of specimens



Determine μ (Fig. 2)

- $V_{al} \rightarrow \mu$
- $\mu_{al} = 0.33$
- $\mu_{plaster} = 0.15$



E v V_{al} Models (Fig. 3)

- Models can be used to predict intermediate values of E
- Theoretical relationships that involve some assumptions
- Parallel and Series Model
- These will be covered in detail with Dr. Weiss

Series E v V_{al} Models (Fig. 3)

Session 1

Setup

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Session 2

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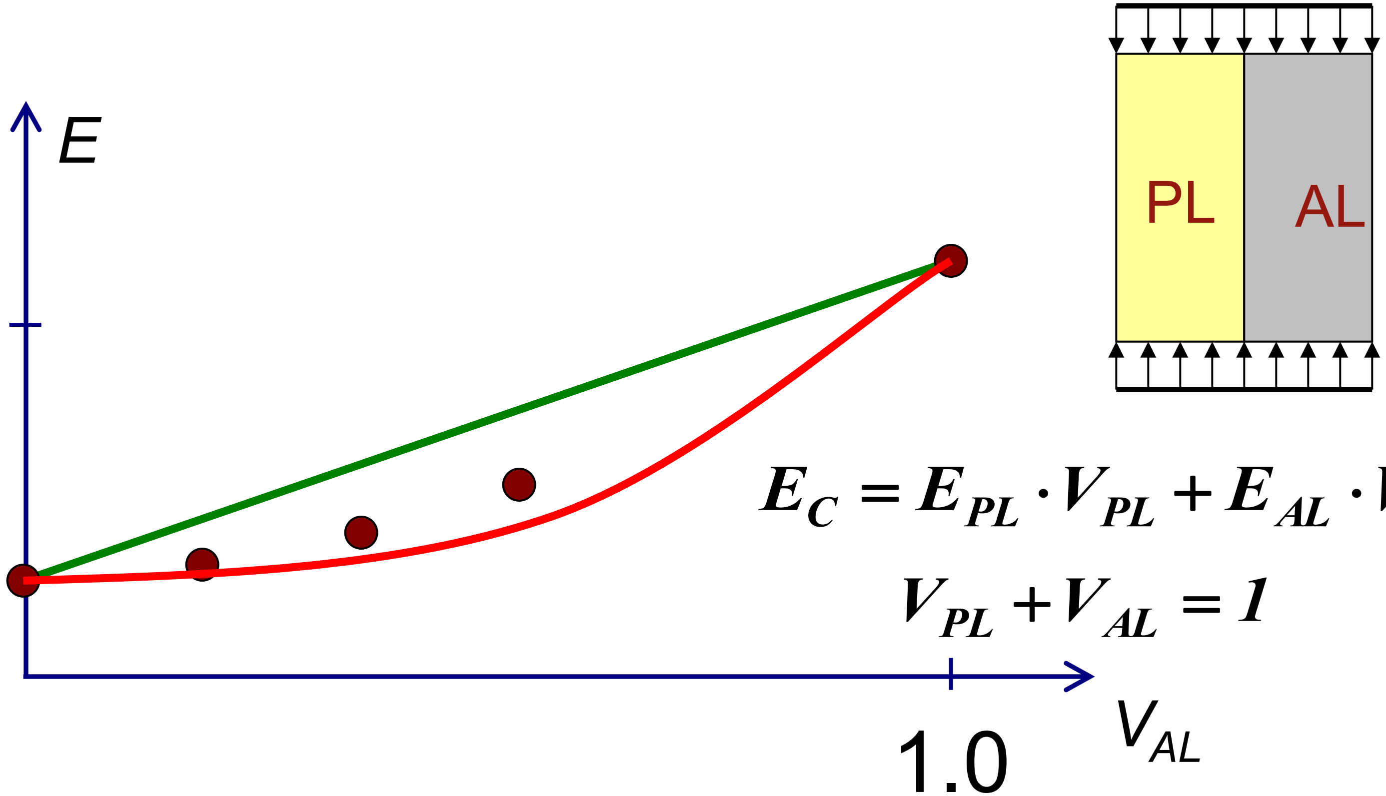
Setup

Task 1

Task 2

Task 3

- Parallel (Voight) Law

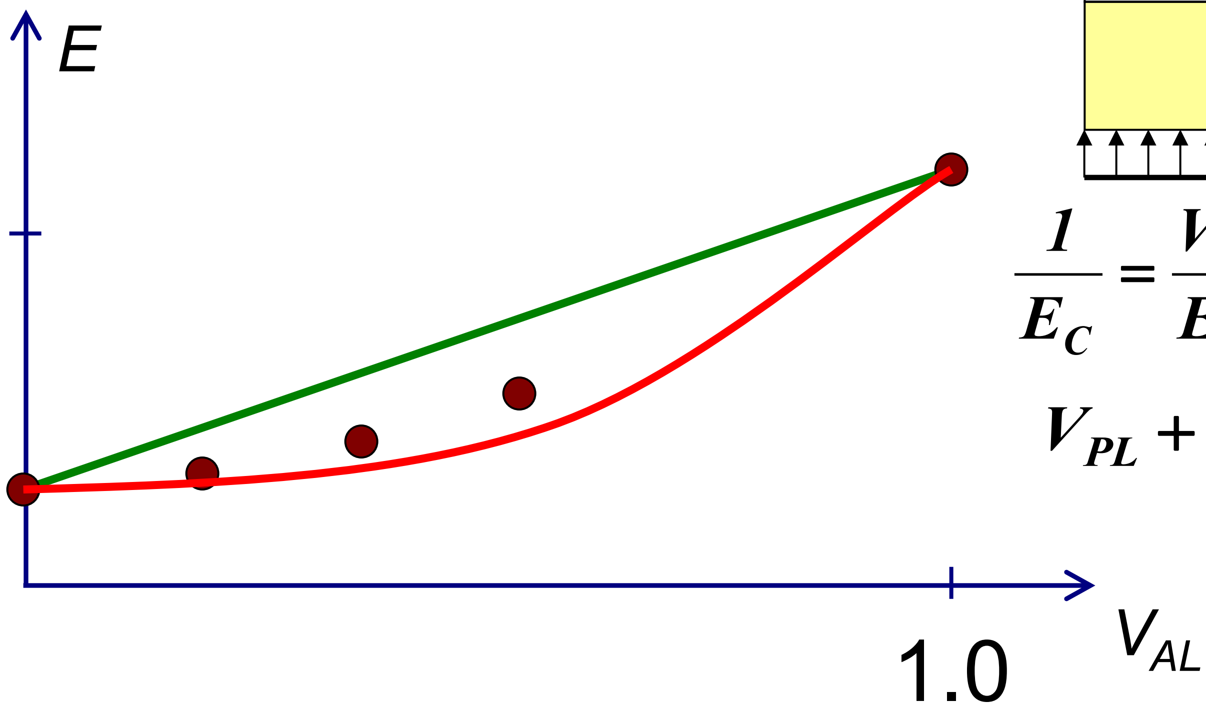


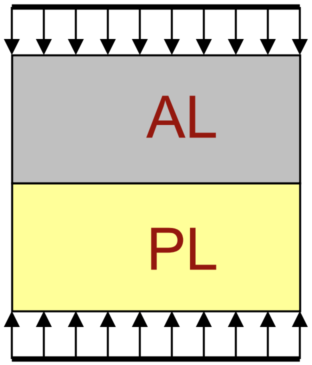
$$E_C = E_{PL} \cdot V_{PL} + E_{AL} \cdot V_{AL}$$

$$V_{PL} + V_{AL} = 1$$

Series E v V_{al} Models (Fig. 3)

- Series (Reuss) Law





$$\frac{1}{E_C} = \frac{V_{PL}}{E_{PL}} + \frac{V_{AL}}{E_{AL}}$$

$$V_{PL} + V_{AL} = 1$$

Model Conventions

Session 1

Setup

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Session 2

Background

Setup

Task 1

Task 2

Task 3

- There are some general rules when showing experimental data and models on the same plot
- Experimental Data
  - Measured points
  - Not connected with a line
- Model Data
  - No data points
  - Continuous: Use lines and a large number of points to define the curve

Report

Session 1

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Session 2

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Setup

Task 1

Task 2

Task 3

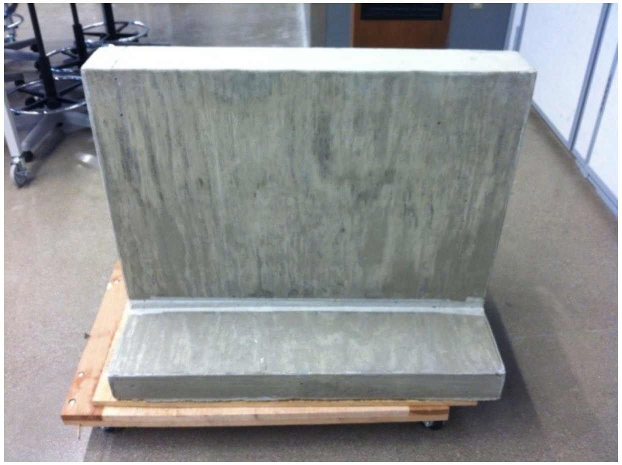
- Summary Table

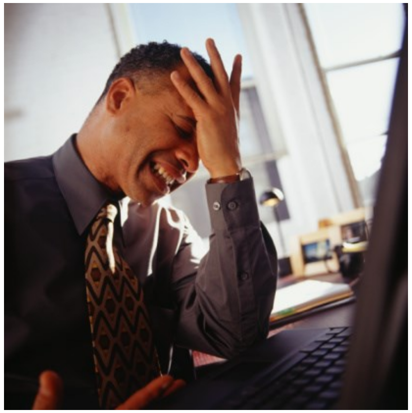
SAMPLE	Density (kg/m³)	V_{al}	Poisson's Ratio μ	Time (µs)	Elastic Modulus (MPa)
1					
2					
3					
Aluminum					
Plaster					

- Figures
  - ρ v V_{al}
  - μ v V_{al}
  - E v V_{al} with both models (make sure to describe these models in the report)

Task 3: Field Investigation

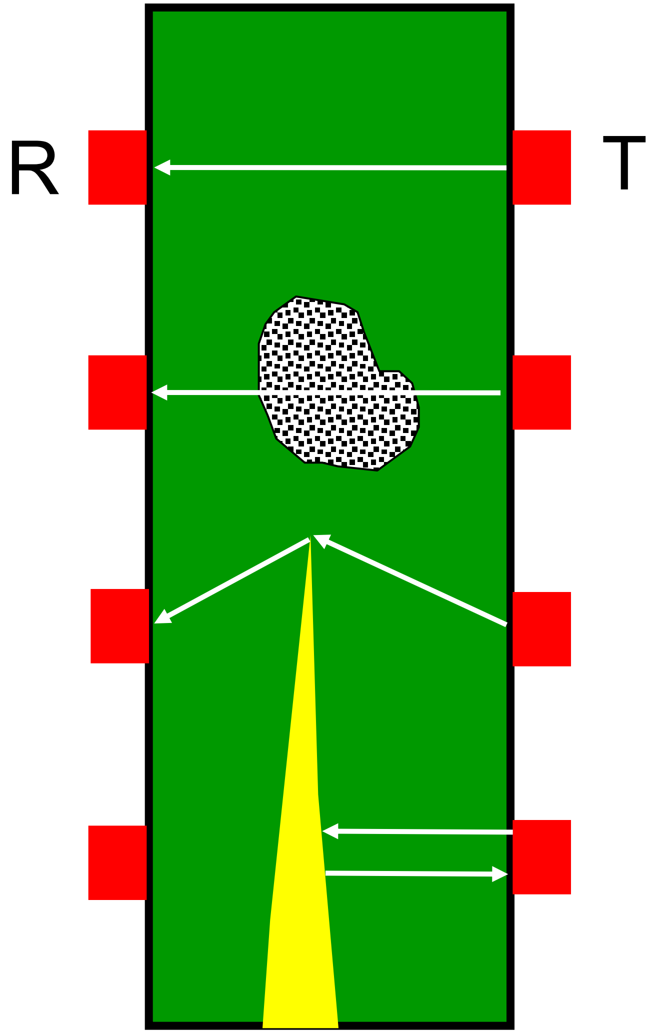
- Movement of a newly constructed wall during loading has raised concerns about the structural integrity of the wall
- The contractor cannot recall if the concrete was properly consolidated during placement





Recall: Through Transmission

- Through thickness CP measurements used to monitor uniformity of in-place concrete.
- Presence of "defect" increases travel time (lower speed).
- Requires access to both sides



Task 3: Field Investigation

Session 1

Setup

Analysis

Report

Session 2

Background

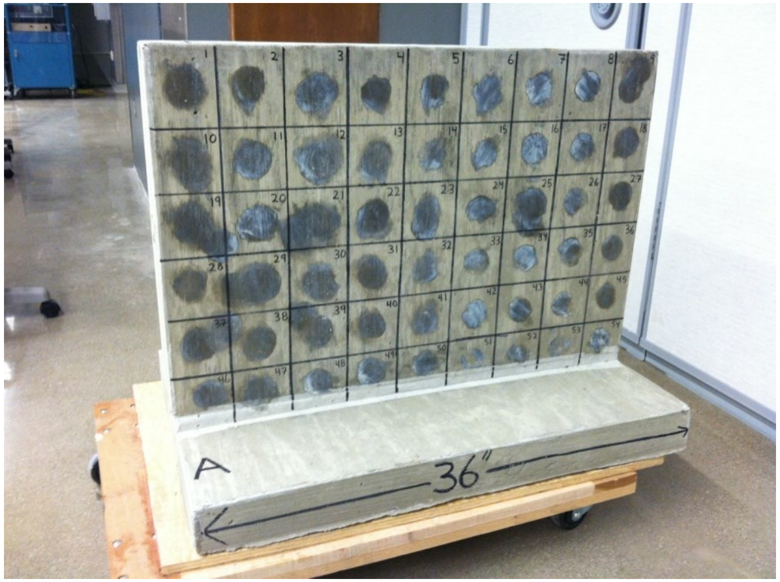
Setup

Task 1

Task 2

Task 3

- Determine sample location and frequency (previously chosen)
- Measure wave travel time at each point, record in table



Task 3: Field Investigation

Session 1

Setup

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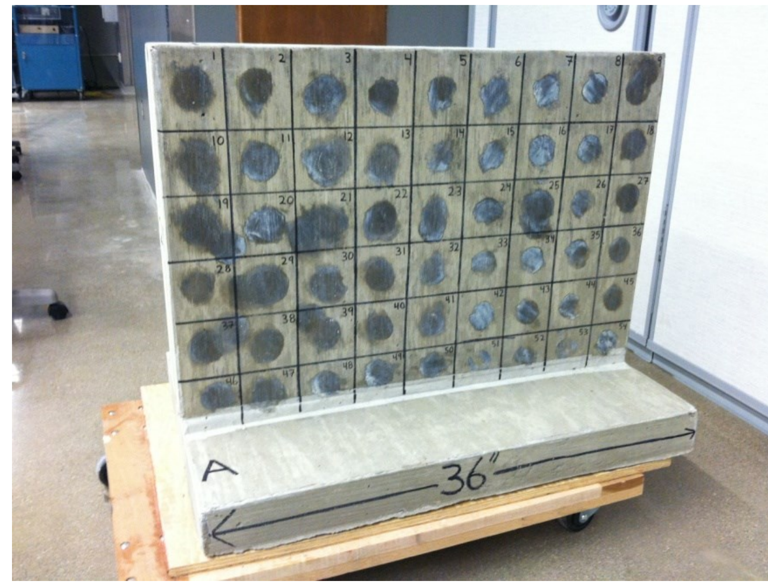
Task 1

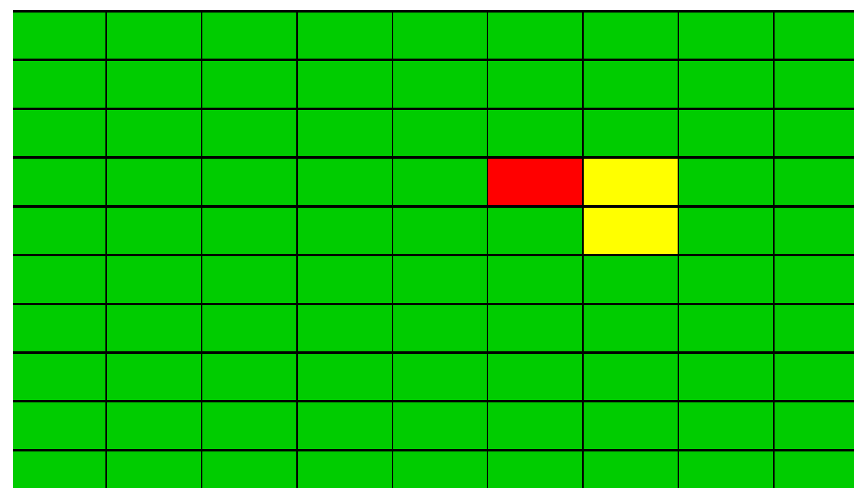
Task 2

Task 3

Create a graphic showing the integrity of the wall based on measurements

- value < 50µs green
- 50µs< value < 100µs yellow
- value>100µs red





Task 3: Report

- Table showing values collected from lab
- Visual graphic showing integrity of the wall
  - Make sure to include a legend
- Discussion of how the defect(s) affected the wave speed within the wall

MAKE SURE TO CHECK THE RUBRICS!

Questions?!