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The Hazards of Shelter

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Two Similar Earthquakes...

| | |
|-----------------------------|---------------------------------|
| ■ San Francisco, USA | ■ Messina, Sicily, Italy |
| ■ Year: 1906 | ■ Year: 1908 |
| ■ Time: 5.12 am | ■ Time: 5.20 am |
| ■ Magnitude: 7.8 | ■ Magnitude: 7.1 |
| ■ Previous EQs: Yes | ■ Previous EQs: Yes |

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Two Similar Earthquakes... ...with different consequences

| | |
|-----------------------------|---------------------------------|
| ■ San Francisco, USA | ■ Messina, Sicily, Italy |
| ■ Year: 1906 | ■ Year: 1908 |
| ■ Time: 5.12 am | ■ Time: 5.20 am |
| ■ Magnitude: 7.8 | ■ Magnitude: 7.1 |
| ■ Previous EQs: Yes | ■ Previous EQs: Yes |
| ■ Population: 355,000 | ■ Population: 150,000 |
| ■ Deaths: 3,000 | ■ Deaths: 70,000 |
| ■ Deaths %: 0.8 | ■ Deaths %: 46.7 |

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Reasons for differences?


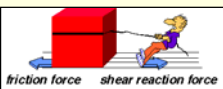


- **Tsunamis?**
 - No major inundations in either event
- **Fire?**
 - **San Francisco's was worse!**
- **Building construction?**
 - **San Francisco: wood**
 - **Messina: stone and brick**



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Forces



- **Can produce motion**
 - But opposing forces can prevent it
- **Types of Forces**
 - *Gravity*: weight of a building
 - *Friction*: between tectonic plates
 - *Buoyancy*: wood in water
 - *Elastic*: spring returning to rest

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Forces

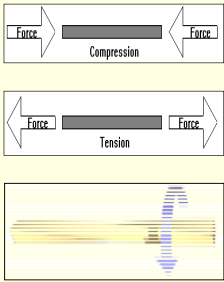
- **Produce stress in materials**
 - Which can cause deformation
- **Deformation depends on...**
 - *Elastic limit*: up to this, no change
 - *Plastic behaviour*: Deformation but no breakage
 - *Ultimate strength*: after this, breaks

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Types of stress on materials

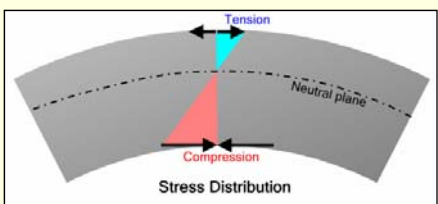
- **Compressive**
 - Pushing (squeezing)
- **Tensile**
 - Pulling
- **Shear**
 - Twisting
 - Includes torsion



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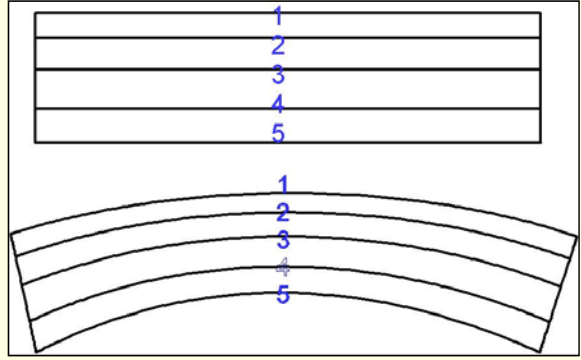
Deformation Experiment

- Deformation due to compression
- Deformation due to tension
- Neutral plane



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Deformation Experiment



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Elastic limits and ultimate strengths of some representative materials (kgf/cm²)

[after Zebrowski 1997, Table 3.1]

| MATERIAL | ELASTIC LIMIT | | ULTIMATE STRENGTH | |
|-------------------|---------------|-------------|-------------------|-------------|
| | TENSION | COMPRESSION | TENSION | COMPRESSION |
| Iron, cast | 420 | 1,800 | 1,400 | 5,600 |
| Steel, structural | 2,500 | 2,500 | 4,600 | 4,600 |
| Brick, best | 30 | 840 | 30 | 840 |
| Granite | 49 | 1,300 | 49 | 1,300 |
| Limestone | 21 | 630 | 21 | 630 |
| Oak, white | 310 | 310 | 600 | 520 |
| Pine, white | 270 | 270 | 400 | 345 |

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Different Building Materials



← San Francisco
Wooden Buildings




Messina
Stone Buildings →

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Different Material Availability

- California: abundant trees



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Different Material Availability

- Sicily: deforested since Romans



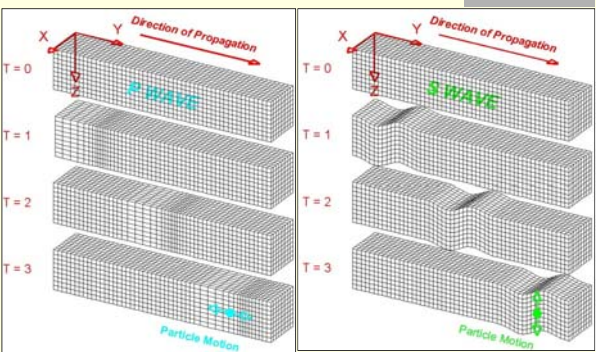
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Types of earthquake waves

- **Body waves** (from hypocentre to surface)
 - **P (primary) waves** (compressional)
 - **S (Secondary, Shear) waves** (distortional, side to side)
- **Surface waves** (from body waves once they reach surface)
 - **Rayleigh, Love, etc.**

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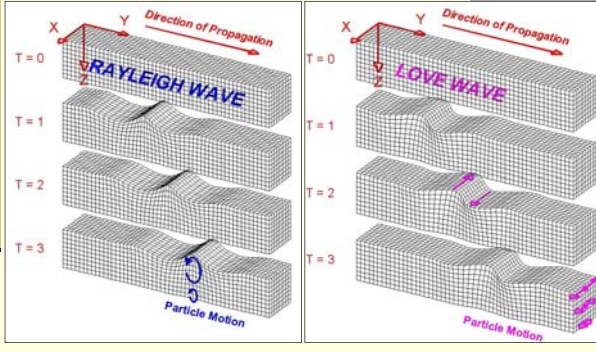
Types of earthquake waves



P Wave **S Wave**

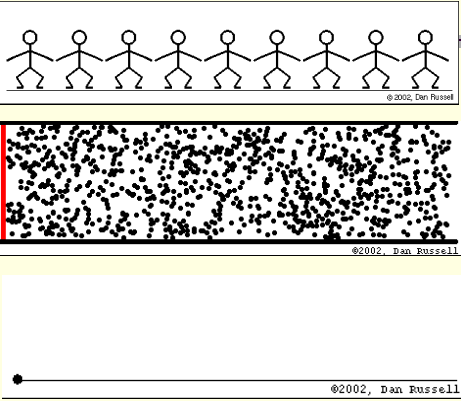
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Types of earthquake waves



RAYLEIGH WAVE **LOVE WAVE**

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- **Stick-slip behaviour of Eqs**
- **EQ prediction?**
 - **Before vs. during vs. after an earthquake**