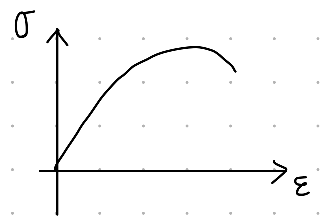
Compression Tests: mechanical test used to determine how a material behaves when compressed, squashed, crushed, or flattened.
-> foams, metal, PET, PVC/ABS pipes, plastics, & rubbers.
-> design process, production environment, Q.C. laboratory.

Concrete



Polyurethane Foam

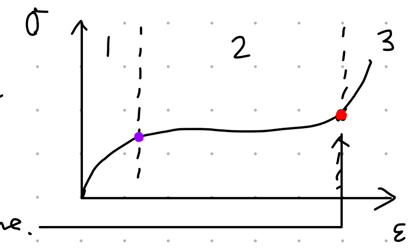
Specimen Preparation: selection of the sample, prep. of sample (cutting/grinding), mounting of the sample (plates/jaws), application of force.

Key Parameters: compression test -> intrinsic properties
- stress (σ), MPa, force applied / unit area
- strain: deform. relative to original length, %
- load: kN, N, applied to specimen
- displacement: mm, cm, movement of specimen

Key Regions:
1. elastic region: behaves elastically & returns to original shape
2. plastic region: after yield pt. & deforms permanently
3. failure region: fractures & fail completely.
4. ultimate compressive strength: Max stress before catastrophic failure.

compressive yield stress: plastics -> pt of permanent yield on curve
metals -> σ corresponding to 0.002 in/in plastic strain

- stress needed to rupture a specimen, harder to find vs tensile test.



Measuring Hardness: resistance of material to surface penetration

Indentation Hardness Test: determines resistance of material to permanent def. when a force is applied.
-> press a hard indenter (diamond or hardened steel) } Brinell / surface abrasion testing
-> resulting indentation is then measured. } Rockwell

Steps: prepare sample -> select indenter & load -> apply the load. -> measure indentation size & depth (microscope) -> calculate hardness value.

indentation: Brinell (hardened steel ball), Rockwell (Diamond cone or hardened steel ball)

micro-indentation: Vickers (diamond pyramid), Knoop (diamond pyramid w/ longer diagonal).

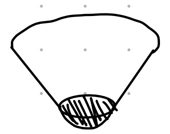
Hardness (H) & Strength (T.S.): often correlate in bulk isotropic materials.
-> mat. can be: very hard (surface) but brittle internally
lower overall strength
-> OR soft but high strength (ductile or tough)

Important Considerations: surface condition / indenter type & load / dwell time (springback of material) / calibration (machine)

Poisson's Ratio: ratio of lateral strain to axial strain under compression
-> (+) means outward expansion of mat. when under compression,
-> 0 means no change in lateral dimension when compressed.
-> (-): inward expansion when comp. (rare!).

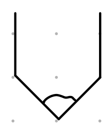
Brinell Test: spherical indenter / straightforward to implement. (indent & then measure)

Limitations: doesn't work for very soft / hard surfaces,
non-ideal for thin specimens,
indent edge less obvious to observe,
inaccurate for low hardness material,
/surface-hardened or painted surfaces.

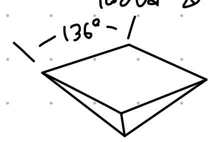


Rockwell Test: applies specified load to indenter / measure.
-> conical indenters + wide variety of other indenters.
-> select load judiciously.
-> more direct results / dial reading / no calc-by-hand needed.

Steps:
Minor load (stabilizes sample & remove inconsistencies),
major load (real test), depth measurement,
hardness calculation, higher hardness number = harder material



Vickers Test: pyramid-shaped, diamond, 136-degree apex angle indenter, can be used for very hard / soft materials
-> diverse materials testing, square-shape indent
-> observed using microscope.
-> Vickers Hardness Value (HV) => calc. using applied load & average diagonal length



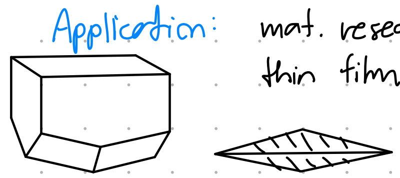
Pros: versatility, precise hardness measurements,
good for delicate mat. (able to use low loads),
good for small scale features (grains).

Common Application: Q.C., failure analysis, mineralogy

Knoop Test: microhardness test for precision & delicate mat.
-> elongated pyramid-shaped diamond indenter
-> 172.5° long & 130° short, <1kg very light loads
-> measures length of longest indentation diagonal,
-> Knoop Hardness Value (HK) => calc. from load & length

Pros: used for extremely small areas & delicate material,
minimizes damage to thin samples/coatings (light),
brittle material compatibility.

Application: mat. research (grains/phases),
thin film analysis.



Compressive modulus of Elasticity: slope of the elastic region of the compression test, Usually, it is > Young's Modulus.

$\varepsilon_\ell = \frac{\Delta \ell}{L}$ longitudinal strain

$\varepsilon_s = \frac{\Delta R}{L}$ transverse strain

$\frac{\varepsilon_s}{\varepsilon_\ell} = \nu$ Poisson's Ratio

3-Point Flexural Test:
measures behav. of mat. in a simple beam loading-geometry
- -> compression, tension, & shear forces.
- -> universal testing machine, 3 or 4-point bend fixture
- -> ease of specimen prep + testing
- -> sensitive to specimen & loading geometry & strain rate (results).

Spring Testing:
Quality assurance purposes.
- -> load capacity / fatigue strength / spring rate
- -> monotonic test w/ end-of-test criteria.
- -> Hooke's Law: deform. ∝ stress applied.

Top-Load / Crush Testing:
crushes samples to a specific distance (1/4") to determine quality.

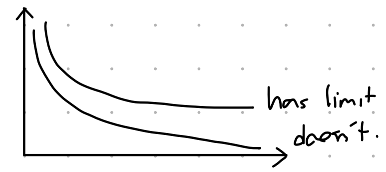
Relevance of Compression Tests:
Q.C., mat. characteristics, R&D, failure analysis

Fatigue:
fail of materials by fracture if they are subjected to repeated applications of stress (90% of all metallic fractures).
- -> fatigue testing
  cyclic load, see how many cycles to cause failure.
  e.g. servo-hydraulic fatigue tester
  fatigue life = # of cycles withstood.
- -> measure
  # of cycles until failure, crack growth rate, stress-strain behavior, material properties, loading conditions, environment.
- -> types: static failure, low cycle fatigue (local plastic strain), high cycle fatigue (local elastic strain).
- -> importance: safe designs, predictive maintenance, material selection.

Endurance:
∝ to the material's tensile strength (not linear & depends on mat).

for steel: TS < 200 kpsi (1400 MPa), $Se = 0.42^* TS$
TS > 200 kpsi (1400 MPa), Se = constant = 100 kPsi (500 MPa)

- -> decreases when temp ↑. more susceptible to fatigue as Temp ↑.
- -> importance: safe designs, reduced fatigue testing, material selection.
- -> not all materials possess an endurance limit!

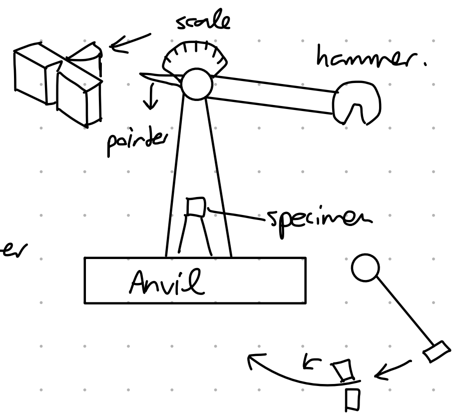


} needs fatigue testing @ lower stress levels

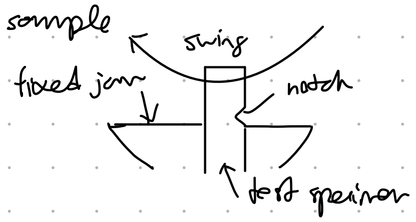
Impact Tests:
measure ability of mat. to resist deform. in response to a sudden load.
- -> Charpy, Izod, drop-weight, dynamic tear tests.
- -> find mat. toughness, establish Q.C. standards.

Impact Strength:
measure of energy required to fracture mat. under impact force. (Joules) & depends on vol. & dist. of F

Charpy V-Notch Test:
pendulum mechanism that swings a hammer onto a V-notched sample
- -> energy absorbed during fracture is in Joules
- -> post-impact travel of the hammer / E dissipated in swing.

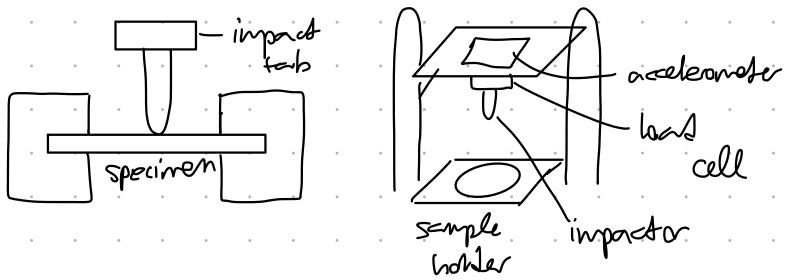


Izod Test:
similar to Charpy, but vertically-oriented sample

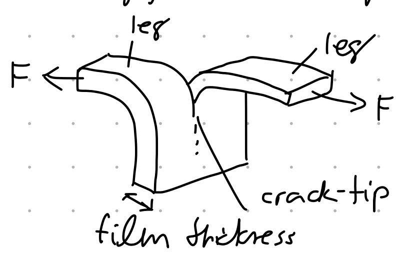


-calculates energy-absorption

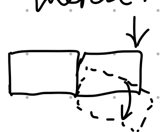
Drop Weight Test:
free falling weight delivers a single-powerful blow to the sample
- -> versatile & handles various materials
- -> measures resistance to shattering / deform.



Dynamic Tear Test:
characterizes textiles & delamination of 3D printed products
- -> energy to tear sample until complete failure



-> vertical comp. for metal:



Impact Strength Factors:
- -> material thickness (volume)
- -> temp (weaker if hotter mostly)
- -> notch radius (sharp, then ↑σ).

Impact Strength Failures
- Brittle fractures: hard material (non-plastic deform) -> 2+ parts
- Ductile fractures: ductile/tough (plastic deform) -> 2 parts/twisted.
- Slight Cracking: success of Charpy & Izod: fracture, if not more energy needed